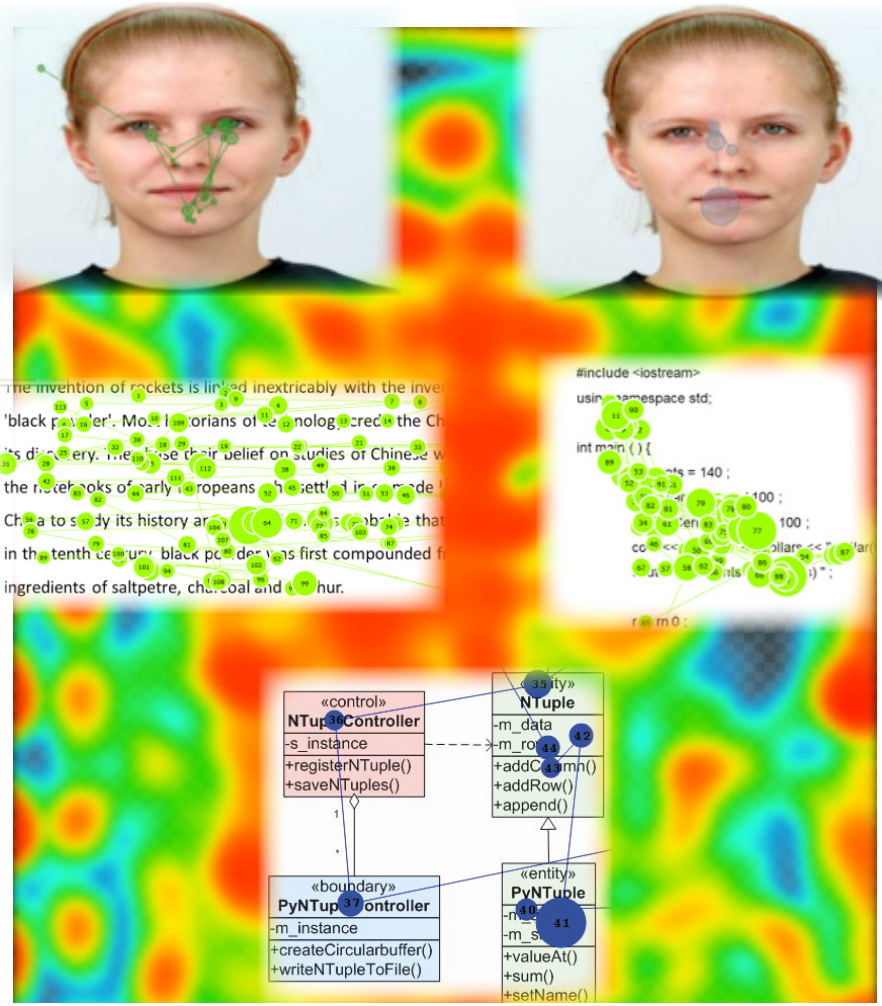
ACM Symposium on Eye Tracking Research & Applications

ETRA • 2018



ACMSIGGRAPH SIGCHI acm

June 14-17 2018, Warsaw, Poland

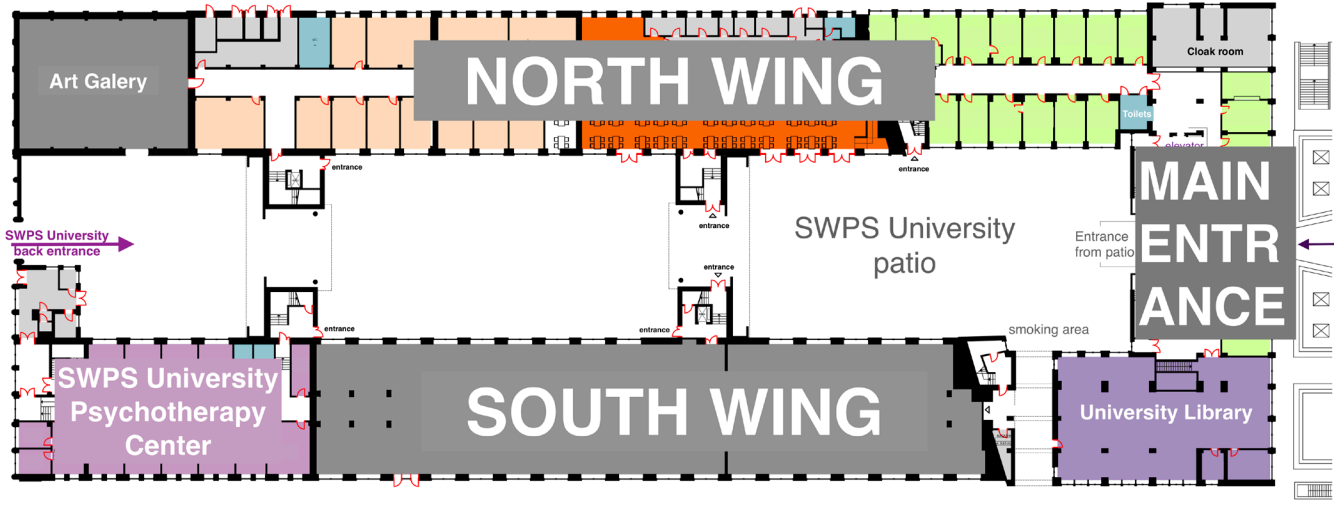
Schedule

	14.06.2018 (Thursday)						15.06.2018 (Friday)			
TIME	**Tutorials Track 1 (room S202)**	**Tutorials Track 2 (room S203)**	**Tutorials Track 3 (room S226)**	**Tutorials Track 4 (room S227)**	**Doctoral Symposium (room S304)**	**TIME**	**Workshops track (S227)**	**Video & Demo/ DS Posters (S302, S304)**	**Talks Track 1 (S214) ETRA poster session (S303)**	**Talks Track 2 (S305)**
9:00 - 10:00	Tutorial 1 - Mehul Bhatt, Jakob Suchan	Tutorial 2- Edward Ryklin	Tutorial 4-Tanja Blascheck, Michael Raschke, Michael Burch	Tutorial 5- Diako Mardanbegi, Thies Pfeiffer	Doc symposium	**9:00 - 10:00**	Opening session Keynote Address - Susanna Martinez-Conde Room S214			
10:00 - 10:30	Coffee break(room S303)					**10:00 - 10:30**	Coffee break(room S303)			
10:30 - 12:30	Tutorial 1 - Mehul Bhatt, Jakob Suchan	Tutorial 2- Edward Ryklin	Tutorial 4-Tanja Blascheck, Michael Raschke, Michael Burch	Tutorial 5- Diako Mardanbegi, Thies Pfeiffer	Doc symposium	**10:30 - 12:30**			ETRA Session 1: Cognition Room: S214	COGAIN Session 1 Room: S305
12:30 - 13:30	Lunch break(room S303)					**12:30 - 13:30**	Lunch break(room S303)			
13:30 - 15:30	Tutorial 3- Andrew Duchowski, Nina Gehrer		Tutorial 4-Tanja Blascheck, Michael Raschke, Michael Burch	Tutorial 5- Diako Mardanbegi, Thies Pfeiffer	Doc symposium	**13:30 - 15:30**	Tobii Workshop Room: (S227)		ETRA Session 2: Fundamental Eye Tracking Room: S214	COGAIN Session 2 Room: S305
15:30 - 16:00	Coffee break(room S303)					**15:30 - 16:00**	Coffee + posters(rooms S303)			
16:00 - 17:00	Tutorial 3- Andrew Duchowski, Nina Gehrer		Tutorial 4-Tanja Blascheck, Michael Raschke, Michael Burch	Tutorial 5- Diako Mardanbegi, Thies Pfeiffer	Doc symposium	**16:00 - 18:00**	SmartEye Workshop Room: (S227)	Video & Demo & DS posters Rooms: S304 & S302	ETRA Poster session Room: S303	PETMEI Session 1 Room: S305
18:00 onwards					Doctoral symposium dinner – sponsored by Microsoft	**19:30 onwards**	Conference gala dinner (Endorfina Foksal Restaurant)			

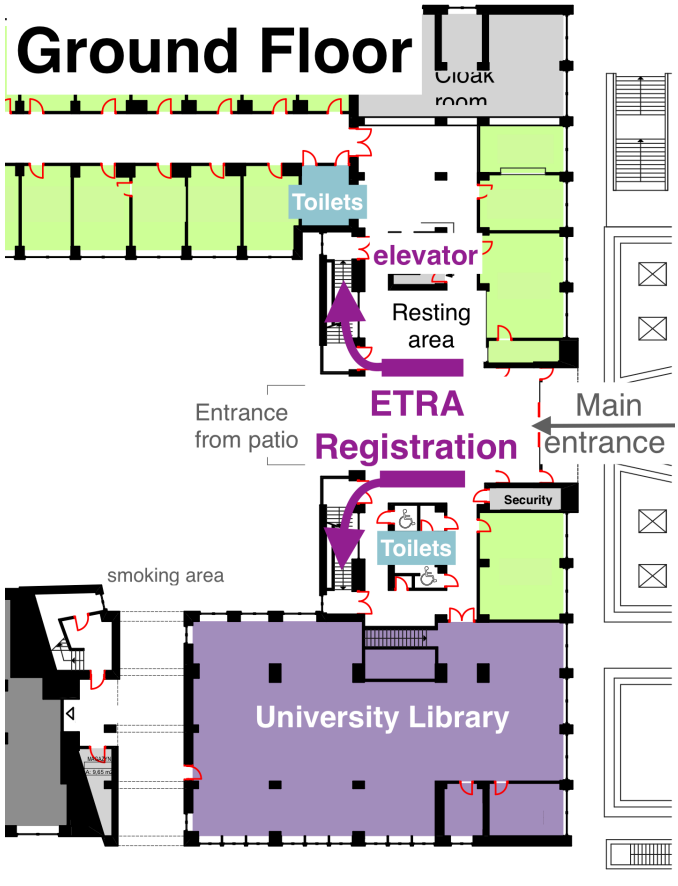
Schedule

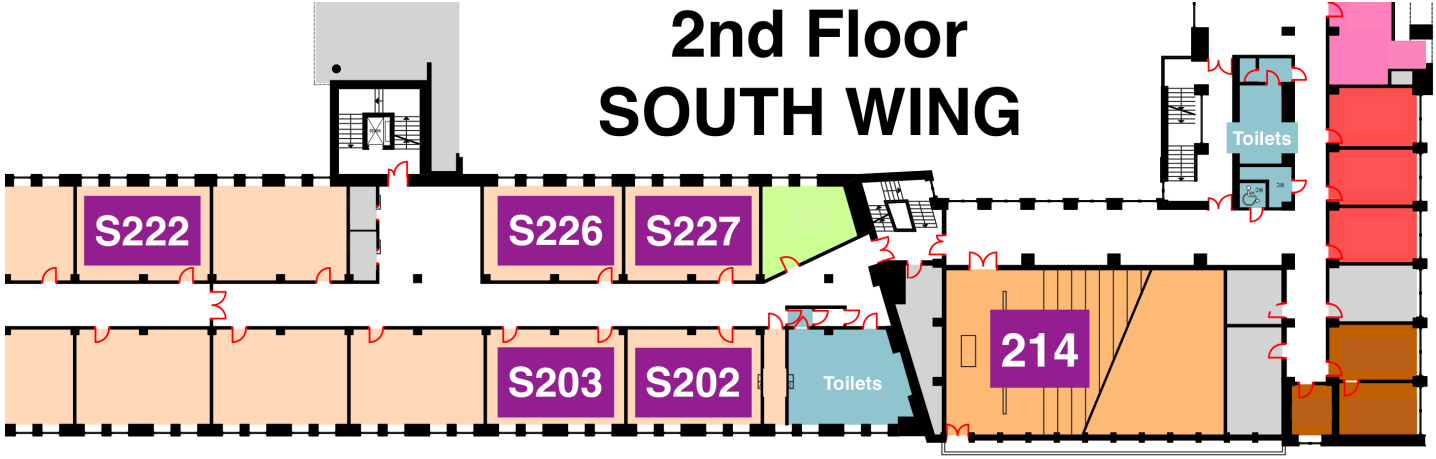
		16.06.2018 (Saturday)			17.06.2018 (Sunday)		
TIME	**Workshops track (S227)**	**Talks Track 1 (S214)**	**Talks Track 2 (S305)**	**TIME**	**Talks Track 1 (S214)**		Talks Track 2 (S305)
9:00 - 10:00		Keynote Address - Andreas Bulling Room S214		**9:00 - 10:00**	Keynote Address - Halszka Jarodzka Room S214		
10:00 - 10:30		Coffee break(room S303)		**10:00 - 10:30**	Coffee break(room S303)		
10:30 - 12:30	Pupil Labs Workshop Room: (S227)	ETRA session 3: Digital Interactions Room: S214	PETMEI Session 2 Room: S305	**10:30 - 12:30**	iMotions Workshop Room: (S227)	ETRA Session 6: Social and Natural Behavior Room: S214	EMIP Session 1 Room: S305
12:30 - 13:30		Lunch break(room S303)		**12:30 - 13:30**	Lunch break(room S303)		
13:30 - 15:30	Oculus Workshop Room: (S227)	ETRA session 4: Mobile Eye Tracking Room: S214	ETVIS Session 1: Visualization Room: S305 ETVIS Session 2: Evaluation Room: S305	**13:30 - 15:30**		ETRA Session 7: Clinical and Emotional Room: S214	EMIP Session 2 Room: S305
15:30 - 16:00		Coffee break(room S303)		**15:30 - 16:00**	Coffee break(room S303)		
16:00 - 18:00		ETRA session 5: Gaze based Interaction Room: S214	ETVIS Session 3: Applications Room: S305 ETVIS – Panel Discussion Room: S305	**16:00 - 18:00**	Town hall meeting, ETRA 2019 Introduction, Farewell Room: S214		

SWPS University
Ground Floor
General Overview



UNIWERSYTET SWPS


Ground Floor
Cloak room
Toilets
elevator
Resting area
ETRA
Registration
Entrance from patio
Main entrance
Security
Toilets
smoking area
University Library



Second Floor


3rd Floor
SOUTH WING
S305
S304
S303
S302
child care room
Toilets
214
Toilets

Third Floor

Table of Contents

Message from Conference Chairs

For twenty years, the ACM Symposium on Eye Tracking Research & Applications (ETRA) has been the premier world-wide meeting place for the eye tracking community. This year ETRA is celebrating its tenth anniversary and for the first time is hosted in Europe, at SWPS University of Social Sciences and Humanities in Warsaw, Poland.

We strongly believe that these proceedings represent the most novel and rigorous eye tracking methodology advances as well as applications in a variety of fields. This year we introduced several novelties to the ETRA conference keeping in mind three points: expanding the scope of the conference, inclusion of more diverse fields of research and strengthening the eye tracking community. First, we introduced colocation with other excellent eye tracking scientific events such as COGAIN (Computer-Gaze Interaction Symposium), PETMEI (International Workshop on Pervasive Eye Tracking and Mobile Eye-Based Interaction), ETVIS (Workshop on Eye Tracking and Visualization), and EMIP (Workshop on Eye Movements In Programming). Second, for the first time, we have parallel sessions due to the number of papers accepted to ETRA and all co-located events. Third, we introduced four free-of-charge commercial workshops proposed by eye tracker vendors and companies developing eye tracking data analysis software. The program also includes full-day and half-day tutorials by experts in the field. ETRA received a total of 223 submissions out of which 29 papers were accepted as long papers and 39 as notes. A poster session was held for all ETRA notes, Doctoral Symposium and Video & Demo papers.

This conference would not have been possible without the efforts of many. We thank all the members of the organizing committee, authors, reviewers, area chairs, and sponsors who provided their time to make ETRA possible. Our goal is for you to have the best possible conference experience,. It has been our pleasure to serve in our capacity of general chairs of ETRA. We wish you a great time in Warsaw, meeting and exchanging ideas with other researchers and building new collaborations in the future.


Bonita Sharif & Krzysztof Krejtz
ETRA 2018 Conference Chairs

THANK YOU TO OUR 2018 CHAIRS

Conference Chairs
Bonita Sharif (Youngstown State University, USA)
Krzyzstof Krejtz (University of Social Sciences and Humanities, Poland)

Paper Chairs
Roman Bednarik (University of Eastern Finland, Finland)
Frederick Shic (Seattle Children's Research Institute/University of Washington, USA)

Demo & Video Chairs
Tanja Blascheck (INRIA, France)
Rakshit Kothari (Rochester Institute of Technology, USA)

Doctoral Symposium Chairs
Hana Vrzakova (University of Eastern Finland, Finland)
Reynold Bailey (Rochester Institute of Technology, USA)
Marcus Nyström (Lund University, Sweden)

Tutorial Chairs
Preethi Vaidyanathan (Rochester Institute of Technology, USA)
Pawel Kasprowski (Silesian University of Technology, Poland)

Poster Chair
Arantxa Villanueva (Public University of Navarra, Spain)

Accessibility Chairs
Justyna Żurawska (SWPS University of Social Sciences and Humanities, Warsaw, Poland)
Maksymilian Bielecki (SWPS University of Social Sciences and Humanities, Warsaw, Poland)

Social Media Chairs
Anna Niedzielska (SWPS University of Social Sciences and Humanities, Warsaw, Poland)
Kamran Binaee (Rochester Institute of Technology, USA)

Web Chair
Jenna Wise (Carnegie Mellon University, USA)

10th Anniversary Celebrations Chair
Dan Witzner Hansen (IT University of Copenhagen, Denmark)

Sponsor Chairs
Oleg Komogortsev (Michigan State University, USA)
Andrew Begel (Microsoft Research, USA)

Proceedings Production Editor
Stephen N. Spencer, University of Washington

Thank you to the ETRA Steering Committee

Andrew Duchowski (Chair)
Pernilla Qvarfordt
Kari-Jouko Räihä

Special thanks to the 245 paper reviewers!

Co-located Event Chairs

EMIP 2018 General Chairs
Roman Bednarik (University of Eastern Finland, Finland)
Carsten Schulte (Paderborn University, Germany)

PETMEI 2018 General Chairs
Andreas Bulling (Saarland University, Germany)
Enkelejda Kasneci (University of Tübingen, Germany)
Christian Lande (German Research Center for Artificial Intelligence, Germany)

COGAIN 2018 General Chairs
Carlos Morimoto (University of São Paulo, Brazil)
Thies Pfeiffer (Bielefeld University, Germany)

ETVIS 2018 General Chairs
Lewis Chuang (University of Tübingen, Germany)
Michael Burch (Eindhoven University of Technology, Netherlands)
Kuno Kurzhals (University of Stuttgart, Germany)

Area Chairs

Andrew Begel	Microsoft Research, USA
Pieter Blignaut	University of the Free State, South Africa
Giuseppe Boccignone	University of Milan, Italy
Andreas Bulling	Max Planck Institute for Informatics, German
Michael Burch	Eindhoven University of Technology, Netherlands
Lewis Chuang	Max Planck Institute for Biological Cybernetics, Germany
Michael Dorr	Technical University of Munich, Germany
Andrew Duchowski	Clemson University, USA
Hans Gellersen	Lancaster University, England
Howell Istance	University of Tampere, Finland
Pawel Kasprowski	Silesian University of Technology, Poland
Peter Kiefer	ETH Zurich, Switzerland
Carlos Morimoto	University of São Paulo, Brazil
Jeff Mullingan	NASA, USA
Marcus Nyström	Lund University, Sweden
John Paulin Hansen	Technical University of Denmark, Denmark
Thies Pfeiffer	Bielefeld University, Germany
Marc Pomplun	University of Massachusetts Boston, USA
Oleg Spakov	University of Tampere, Finland
Yusuke Sugano	Osaka University, Japan
Quan Wang	Yale University, USA
Bin Zheng	University of Alberta, Canada

Special thanks to Patrick Peachock for designing
and editing the conference booklet

KEYNOTE
Friday 15.06.2018 - 9:15

From fixation to exploration: Towards an integrative view of oculomotor function

SUSANA MARTINEZ-CONDE, PROFESSOR AT THE STATE UNIVERSITY OF NEW YORK (SUNY), USA

Abstract: Vision depends on motion: we see things either because they move or because our eyes do. What may be more surprising is that large and miniature eye motions help us examine the world in similar ways - largely at the same time. In this presentation, I will discuss recent research from my lab and others suggesting that exploration and gaze-fixation are not all that different processes in the brain. Our eyes scan visual scenes with a same general strategy whether the images are huge or tiny, or even when we try to fix our gaze. These findings indicate that exploration and fixation are not fundamentally different behaviors, but rather two ends of the same visual scanning continuum. They also imply that the same brain systems control our eye movements when we explore and when we fixate - an insight that may ultimately offer clues to understanding both normal oculomotor function in the healthy brain, and oculomotor dysfunction in neurological disease.

Bio: Susana Martinez-Conde is a Professor of Ophthalmology, Neurology, and Physiology & Pharmacology at the State University of New York (SUNY) Downstate Medical Center, where her research program bridges perceptual, oculomotor, and cognitive neuroscience. She directed laboratories previously at the Barrow Neurological Institute in Phoenix and at University College London in the UK. She received her postdoctoral training from Nobel Laureate Prof. David Hubel at Harvard Medical School, where she was later an Instructor in Neurobiology.

Prof. Martinez-Conde received the Empire Innovator Award from the State of New York. Her work with Parkinsonian patients was honored with the EyeTrack Award, a global science prize given annually to a single cutting-edge publication in eye movement research. Prof Martinez-Conde has received various other distinctions, including the “100 Spaniards” Prize. She complements her award-winning research with science communication, education and public outreach. She writes for Scientific American and has a regular column in Scientific American: MIND on the neuroscience of illusion. Prof. Martinez-Conde is the 2014 recipient of the Science Educator Award, given by the Society for Neuroscience to an outstanding neuroscientist who has made significant contributions to educating the public.

Prof. Martinez-Conde's research has been featured in print in The New York Times, The New Yorker, The Wall Street Journal, Wired, The LA Chronicle, The Times (London), The Chicago Tribune, The Boston Globe, Der Spiegel, etc., and in radio and TV shows, including Discovery Channel's Head Games and Daily Planet shows, NOVA: ScienceNow, CBS Sunday Morning, NPR's Science Friday, and PRI's The World. She works with international science museums, foundations and nonprofit organizations to promote neuroscience education and communication. Her international bestselling book ‘Sleights of Mind’ was published in 21 languages, listed as one of the 36 Best Books of 2011 by The Evening Standard, London, and received the Prisma Prize to the best science book of the year. Her new book, ‘Champions of Illusion,’ was published by Scientific American/Farrar, Straus and Giroux.

KEYNOTE
Saturday 16.06.2018 - 9:00

Pervasive Gaze Sensing, Analysis, and Interaction: The New Frontier

ANDREAS BULLING, MAX-PLANCK INSTITUTE FOR INFORMATICS, GERMANY

Abstract: The measurement, analysis, and use of human gaze has a long history in various academic disciplines and in industry but has long been limited to special application domains or user groups. Driven by the recent commercial breakthrough of virtual and augmented reality technology, as well as the advent of affordable stationary and head-mounted eye trackers, gaze interfaces are on the verge to finally become available in a wide range of consumer applications and to be used by millions of users on a daily basis. These latest advances pose an important question - what is next?

In my talk I will argue for a new frontier in eye tracking research: The development of pervasive attentive user interfaces that sense, analyse, and adapt to users' gaze in all explicit and implicit interactions that users perform with machines in everyday life. These new interfaces will go far beyond current interfaces that still require (partly) controlled environments, that assume gaze input to be deliberately triggered by users, that often consider the point of gaze as the only gaze characteristic, and that are geared to temporary interactions. Pervasive attentive user interfaces promise exciting new applications that, for example, sense gaze robustly, accurately, and seamlessly across arbitrary devices and systems, that analyse gaze behaviour continuously over long periods of time in daily life, and that combine gaze with other input modalities to enable truly natural, intuitive, and expressive interactions with machines.

Bio: Dr. Andreas Bulling is head of the independent research group Perceptual User Interfaces at the Max Planck Institute for Informatics and the Cluster of Excellence on Multimodal Computing and Interaction (MMCI) at Saarland University. He received his MSc. in Computer Science from the Karlsruhe Institute of Technology (KIT), Germany, focusing on embedded systems, robotics, and biomedical engineering. He holds a PhD in Information Technology and Electrical Engineering from the Swiss Federal Institute of Technology (ETH) Zurich, Switzerland.

Andreas Bulling was previously a Feodor Lynen Research Fellow and a Marie Curie Research Fellow in the Computer Laboratory at the University of Cambridge, UK, a postdoctoral research associate in the School of Computing and Communications at Lancaster University, UK, as well as a Junior Research Fellow at Wolfson College, Cambridge. He is UbiComp steering committee member and serves on the editorial boards of the Proceedings of the ACM on Interactive, Mobile, Wearable, and Ubiquitous Technologies, ACM Transactions on Interactive Intelligent Systems, and the Journal of Eye Movement Research. He also served as co-chair, TPC member and reviewer for major conferences, most recently as TPC co-chair for ACM UbiComp 2016 and IEEE PerCom 2015 as well as associate chair for ACM ETRA 2016 and 2018, as well as ACM CHI 2013, 2014, and 2018. In 2011 he founded the International Workshop Series on Pervasive Eye Tracking and Mobile Eye-Based Interaction (PETMEI), co-located with ACM UbiComp, ECEM, and ACM ETRA.

KEYNOTE
Sunday 17.06.2018 - 9:00

Eye tracking in Education – bridging the gap from fundamental research to educational practice

HALSZKA JARODZKA, ASSOCIATE PROFESSOR AT THE WELTEN INSTITUTE,
NETHERLANDS

Abstract: Over the past decade, eye tracking has shed light onto aspects of learning and instruction that could not have been addressed otherwise before. However, few of these insights have found their way to educational practice. To bridge this gap between this fundamental research and educational practice, we now must take a step from controlled laboratory settings towards real-life scenarios accounting for their full complexity.

In my keynote, I would like to address this question from three perspectives, namely by using eye tracking to analyze the viewpoint of the teacher as well as that of the student, and by using eye tracking as direct instruction tool. From the teacher's perspective, I will focus on how teachers develop visual expertise in managing a classroom full of students and how this can be investigated by eye tracking (and other triangulating measures). From the students' perspective, I will discuss how eye tracking can help us to improve the instructional design of computer-based learning- and testing environments and what influence social presence has on students' attentional processes and ultimately on their learning. Finally, I will present how we use eye tracking directly for teaching by means of so-called eye movement modeling examples, which is a form of video-based instruction, and what guidelines we can derive thus far for their design.

For all three aspects, I will draw connections to other areas of eye tracking research to show what we learned from them and described what theoretical development our research aims at.

Bio: Dr. Halszka Jarodzka works as an associate professor at the Welten Institute, Research Centre for Learning, Teaching and Technology at the Open University of the Netherlands, where she chairs a research group on eye tracking in education (https://www.ou.nl/welten-learning-and-expertise-development). She also works part-time as a visiting scholar at the eye tracking laboratory of Lund university in Sweden (http://projekt.ht.lu.se/en/digital-classroom/). Furthermore, she is the founder and coordinator of the Special Interest Group "online measures of learning processes" of the European Association of Research on Learning and Instruction (https://www.earli.org/node/50). Her main research interest lie in the use of eye tracking to understand and improve learning, instruction, and expertise development.

Sponsor Workshops

Eye Tracking at Oculus Research : Revisiting the Fundamentals (Saturday 16.06 13:30-15:30)

Robert Cavin (Research Lead)

Eye tracking technology has been available in some form for decades. However, truly immersive VR and AR experiences require great eye tracking, all the time, for every user with virtually no allowance for weight, power, conspicuity, or compute. Traditional tracking technologies do not meet all of these stringent criteria, and it's unclear if more engineering effort will get us there. The field requires fundamental research to challenge long-standing assumptions in eye tracking best practices. In this talk, we'll provide an overview of the approach at Oculus Research, and dive deep on many of the challenges that face the community. We look forward to collaborating with researchers and industry partners to unlock the true potential of VR/AR though great eye tracking.

Eye tracking philosophy from Tobii Pro (Friday 15.06, 13:30 - 15:30)

Anders Kingbäck (Senior Algorithm Developer)

This workshop will focus on the human eye movements and how to measure them from a physical and geometrical point of view, as opposed to the more common topic of the cognitive aspects of eye movements. There will be a walk through different parts of the human eye and muscles controlling it (including both optical and mechanical behavior). Followed by a brief discussion around different types of eye movements and gaze behavior and how these correlate to the eye mechanics (saccades, fixations, smooth pursuit, VOR, accomodation and vergence). A short introduction to different methods of measuring eye movements will be given, leading to a more detailed discussion about the design philosophy behind Tobii eye trackers and how they take into account the optical and geometrical aspects of eye movements, as described in the beginning. All parameters in the output data will be described in detail, with reference to the geometrical behavior of a real human eye.

Hands-on with Pupil Labs - Current features and future directions (Saturday 16.06, 10:30 - 12:30)

Kai Dierkes, Ching-Ting Huang,Moritz Kassner, Will Patera, Bernhard Petersch, Pablo Prietz, Marc Tonsen

This workshop will provide a brief introduction to the mobile eye-tracking solutions and software ecosystem developed by Pupil Labs. In a hands-on demonstration and live-coding session, we will give a practical guide to leveraging the Pupil Labs open tool chain. Going forward, the team will present current development and research projects at Pupil Labs and in particular discuss how they utilise modern machine learning and computer vision methods.

Remote Eye Tracking - Challenges and Future (Friday 15.06, 16:00 - 18:00)

Jörgen Thaung (MSC, PhD, Smart Eye Research Scientist), Ulf Löfberg (Area Sales Manager) Gabriel Nyström (Regional Sales Manager)

Smart Eye AB is a Swedish company with a 20 year track record as for remote head- and eye tracking. Serving demanding industries such as the Automotive and Aviation means that R&D is a vital part of Smart Eye operations. To achieve benchmark performance and robustness within human factors is a challenge. The workshop will present and discuss some of the areas crucial for remote tracking. Such as illumination technologies, where Smart Eye tracking algorithm is invariant to changing lighting levels. Remote tracking of subjects wearing a face mask is another challenge. Also we will present our team work using neural networks. Smart Eye technology is operational within different industries. These have shaped the evolution of the Smart Eye PRO system. Different challenging setups such as control rooms and different simulators will be presented where being non-intrusive is the absolute requirement. The workshop will conclude with a Q&A session.

iMotions Workshop (Sunday 17.06, 10:30 - 12:30)

Jeff Zornig, Kerstin Wolf, and Ole Baunbæk Jensen

Join our iMotions workshop and learn how biometric techniques and our platform are being utilized in human behavior research. We will start with a short presentation about biometrics, continue with a 1-hour long interactive DEMO study, and finish with a discussion where our biometric research experts, Jeff Zornig, Kerstin Wolf, and Ole Baunbæk Jensen will answer any of your questions.

Doctoral Symposium

[DS1] **Training Operational Monitoring in Future ATCOs Using Eye Tracking**
Carolina Barzantny (DLR German Aerospace Center)

[DS2] **Automatic detection and inhibition of neutral and emotional stimuli in post-traumatic stress disorder: an eye-tracking study**
Wivine Blekic (University of Mons) and Mandy Rossignol (University of Mons)

[DS3] **Audio-visual interaction in emotion perception for communication**
M.J. de Boer (University Medical Center Groningen); D. Başkent (University Medical Center Groningen); F.W. Cornelissen (University Medical Center Groningen)

[DS4] **Asynchronous Gaze Sharing: Towards a Dynamic Help System to Support Learners During Program Comprehension**
Fabian Deitelhoff (University of Applied Sciences and Arts Dortmund)

[DS5] **Investigating the multicausality of processing speed deficits across developmental disorders with Eye Tracking and EEG**
Sabine Dziemian (University of Zurich)

[DS6] **Using eye tracking to simplify screening for visual field defects and improve vision rehabilitation**
Birte Gestefeld (University Medical Center Groningen); Alessandro Grillini (University Medical Center Groningen); Jan-Bernard Marsman (University Medical Center Groningen); Frans W. Cornelisssen (University Medical Center Groningen)

[DS7] **Intelligent cockpit: eye tracking integration to enhance the pilot-aircraft integration**
Christophe Lounis (ISAE-SUPAERO); Vsevolod Peysakhovich (ISAE-SUPAERO); Mickael Causse (ISAE-SUPAERO)

[DS8] **Eye-tracking measures in audiovisual stimuli in infants at high genetic risk for ASD: challenging issues**
Itziar Lozano (Universidad Autónoma de Madrid); Ruth Campos (Universidad Autónoma de Madrid); Mercedes Belinchón (Universidad Autónoma de Madrid)

[DS9] **Virtual Reality as a Proxy for Real-Life Social Attention?**
Marius Rubo (University of Wuerzburg); Matthias Gamer(University of Wuerzburg)

[DS10] **Towards Concise Gaze Sharing**
Christian Schlösser (University of Applied Sciences and Arts Dortmund)

[DS11] **Seeing into the music score: Eye-tracking and sight-reading in a choral context**
Maria Timoshenko (Åbo Akademi University)

[DS12] **Seeing in Time - An Investigation of Entrainment and Visual Processing in Toddlers**
Hsing-fen Tu (Max Planck Institute for Human Cognitive and Brain Sciences)

[DS13] **A Text Entry Interface using Smooth Pursuit Movements and Language Model**
Zhe Zeng (Technische Universität Berlin); Matthias Roetting (Technische Universität Berlin)

Half Day Tutorials
9:00 - 12:30

Tutorial 1
Spatial Cognition in the Wild — Methods for Large-Scale Behavioural Research in Visuo-Locomotive Perception
Mehul Bhatt (Örebro University, Sweden And University of Bremen, Germany)
Jakob Suchan (University of Bremen, Germany)

The tutorial on Spatial Cognition in the Wild presents an interdisciplinary perspective on conducting evidence-based human behaviour research from the viewpoints of spatial cognition and computation, environmental psychology, and visual perception. The tutorial emphasises the semantic interpretation of multimodal behavioural data, and the (empirically-driven) synthesis of embodied interactive experiences in real world settings. Of special focus are: visual (e.g., perception, attention based on eye-tracking), visuolocomotive (e.g., movement, indoor wayfinding), and visuo-auditory (e.g., moving images) cognitive experiences in the context of areas such as architecture & built environment design, narrative media design, product design, cognitive media studies (e.g., film, animation, immersive reality). The technical focus of the tutorial is on demonstrating general computational methods, tools, and cognitive assistive technologies that can be used for multi-modal human behaviour studies in visual, visuo-locomotive, and visuo-auditory perception. Presented methods are rooted in foundational research in artificial intelligence, spatial informatics, and human-computer interaction. The tutorial utilises case-studies from large-scale experiments in domains such as evidence-based architecture design, communication and media studies, and cognitive film studies to demonstrate the application of the foundational practical methods and tools.

Tutorial 2
Eye movement metrics: event detection
Eward Ryklin (Software Architect, Vision Research, Burke Medical Research Institute, New York, USA)

Event detection, is an end point critical to eye movement applications. Be it gaze interaction or passive attention analysis, software needs to be aware of the user's instantaneous state. Typically, eye movement metrics such as fixation duration (dwell time) modulates a behavioral event; i.e. actuate a button press or similar response that indicate a decision has been made.

I will describe numerous metrics, how they might be derived, and then used to score various behavioral events. Included in the tutorial will be a discussion on the significance of spatial calibration, and techniques to accommodate lack thereof. Also the significance of temporal frequency, i.e. sample rate to derive certain eye metrics and how interaction with temporal artifact filters can delay event detection and impede system performance.

Half Day Tutorials
13:30 - 17:00

Tutorial 3
Gaze Analytics Pipeline
Andrew Duchowski (Clemson University, USA)
Nina Gehrer (University of Tübingen, Germany)

This tutorial presents details of a Python-based gaze analytics pipeline developed and used by Prof. Duchowski and Ms. Gehrer. The gaze analytics pipeline consists of Python scripts for extraction of raw eye movement data, analysis and event detection via velocity-based filtering, collation of events for statistical evaluation, analysis and visualization of results using R. The tutorial is couched in analysis of gaze data collected during discrimination of different emotional expressions while viewing faces. The tutorial covers basic eye movement analytics, e.g., fixation count and dwell time within AOIs, as well as advanced analysis using gaze transition entropy. Newer analytical tools and techniques such as microsaccade detection and the Index of Pupillary Activity will be covered with time permitting.

Full Day Tutorials
9:00 - 17:00

Tutorial 4
Eye-Tracking and Visual Analytics

Tanja Blascheck (Inria, Université Paris Saclay, France)
Michael Raschke (Blickshift Analytics, Germany)
Michael Burch (Eindhoven University of Technology, Netherlands)

Eye tracking has become a widely used method to analyze human behavior in marketing, neuroscience, human-computer interaction, perception and cognition research, as well as visualization. Apart from measuring completion times and recording accuracy rates of correctly given answers during the performance of visual tasks in classical controlled experiments, eye tracking-based evaluations provide additional information on how visual attention is distributed and how it changes for a presented stimulus. Due to the wide field of applications of eye tracking and various kinds of research questions, different approaches have been developed to analyze eye movement data such as statistical algorithms (either descriptive or inferential), string editing algorithms, visualization-related techniques, and visual analytics techniques. Regardless of whether statistical or visual methods are used for eye movement data analysis, a large amount of data generated during eye tracking experiments has to be handled.

Where statistical analysis mainly provides quantitative results, visualization techniques allow researchers to analyze different levels and aspects of the recorded eye movement data in an explorative and qualitative way. When visualization techniques are not able to handle the large amount of eye movement data, the emerging discipline of visual analytics can be an option for exploratory data analysis. Machine-based analysis techniques such as methods from data mining or knowledge discovery in databases are combined with interactive visualizations and the perceptual abilities of a human viewer. Due to the increasing complexity of tasks and stimuli in eye tracking experiments, we believe that visual analytics approaches will play an increasingly important role in future eye tracking research. However, researchers are still missing sophisticated tools for an analysis of eye movement data using visual analytics approaches.

In this tutorial, we will present an overview of visual analytics approaches for eye movement data. We also demonstrate the analysis of eye movement data using Blickshift Analytics, a visual analytics software, which includes different eye tracking visualizations, pattern search techniques, and statistical method.

Full Day Tutorials
9:00 - 17:00

Tutorial 5
Eyetracking in Virtual and Augmented Reality

Diako Mardanbegi, Lancaster University, England
Thies Pfeiffer, Bielefeld University, Germany

Virtual and augmented reality (VR/AR) are highly attractive application areas for eye tracking. Virtual environments have the potential to revolutionize life-sized interactive experimentation under highly-controlled conditions. VR simulations are thus attractive for many fields of research, such as marketing research, human-computer interaction, robotics or psychology. As virtual and augmented reality today primarily address the visual modality, they are well suited for gaze-based interaction, either for direct control or to realize attention aware interactions.

The tutorial provides hands-on experiences with several hardware combinations of VR/AR (e.g. HTC Vive, Microsoft HoloLens) and eye tracking systems (e.g. Pupil, Tobii). In the first half of the tutorial (morning session), an introduction about eye tracking in VR/AR, its potential applications and current solutions will be given. Participants will also get familiar with basic setups of an eye tracking project in Unity3D. In the afternoon session, the focus will be on how gaze can be mapped to 3D objects, how 3D attention can be analyzed and, how gaze can be used to interact with the virtual world. Finally, there will be some hands-on activities where participants can experiment with eyetracking VR/AR setups and do some example projects in Unity3D on both gaze interaction and attention analysis.

As software framework, Unity3D will be used to implement the virtual environments. Basic knowledge of Unity3D is required to get the most out of the hands-on part. The example project and assets will be provided to all participants, which allows for an easy implementation of VR/AR projects with eye tracking.

ETRA Session 1: Cognition 10:30 - 12:30

Session Chair: Frederick Shic

Paper **An investigation of the effects of n-gram length in scanpath analysis for eye-tracking research**

Manuele Reani(The University of Manchester); Niels Peek; Caroline Jay

Scanpath analysis is a controversial and important topic in eye tracking research. Previous work has shown the value of scanpath analysis in perceptual tasks; little research has examined its utility for understanding human reasoning in complex tasks. Here, we analyze n-grams, which are continuous ordered subsequences of participants' scanpaths. In particular we studied the length of n-grams that are most appropriate for this form of analysis. We re-use datasets from previous studies of human cognition, medical diagnosis and art, systematically analyzing the frequency of n-grams of increasing length, and compare this approach with a string alignment-based method. The results show that subsequences of four or more areas of interest may not be of value for finding patterns that distinguish between two groups. The study is the first to systematically define the parameters of the length of n-gram suitable for analysis, using an approach that holds across diverse domains.

Paper **Evaluating gender difference on algorithmic problems using eye-tracker**

Unaizah Obaidellah (University of Malaya); Mohammed Al Haek (University of Malaya)

Gender differences in programming comprehension has been a topic of discussion in recent years. We conducted an eye-tracking study on 51(21 female, 30 male) computer science undergraduate university students to examine their cognitive processes in pseudocode comprehension. We aim to identify their reading strategies and eyegaze behavior on the comprehension of pseudocodes in terms of performance and visual effort when solving algorithmic problems of varying difficulty levels. Each student completed a series of tasks requiring them to rearrange randomized pseudocode statements in a correct order for the problem presented. Our results indicatedthat the speed of analyzing the problems were faster among male students, although female students fixated longer in understanding the problem requirements. In addition, female students more commonly fixated on indicative verbs (i.e., prompt, print), while male students fixated more on operational statements (i.e., loops,variables calculations, file handling).

10:30 - 12:30
ETRA Session 1: Cognition

Note **How many words is a picture worth? Attention allocation on thumbnails versus title text regions**

Chaitra Yangandul (University of Florida); Sachin Paryani (CISE); Madison Le (Google); Eakta JAIN (University of Florida)

Cognitive scientists and psychologists have long noted the “picture superiority effect”, that is, pictorial content is more likely to be remembered and more likely to lead to an increased understanding of the material. We investigated the relative importance of pictorial regions versus textual regions on a website where pictures and text co-occur in a very structured manner: video content sharing websites. We tracked participants’ eye movements as they performed a casual browsing task, that is, selecting a video to watch. We found that participants allocated almost twice as much attention to thumbnails as to title text regions. They also tended to look at the thumbnail images before the title text, as predicted by the picture superiority effect. These results have implications for both user experience designers as well as video content creators.

Paper **Cross-subject workload classification using pupil-related measures**

Tobias Appel (University of Tübingen); Christian Scharinger (Knowledge Media Research Center); Peter Gerjets (Knowledge Media Research Center); Enkelejda Kasneci (University of Tübingen)

Real-time evaluation of a person’s cognitive load can be desirable in many situations. It can be employed to automatically assess or adjust the difficulty of a task, as a safety measure, or in psychological research. Eye-related measures, such as the pupil diameter or blink rate, provide a non-intrusive way to assess the cognitive load of a subject and have therefore been used in a variety of applications. Usually, workload classifiers trained on these measures are highly subject-dependent and transfer poorly to other subjects. We present a novel method to generalize from a set of trained classifiers to new and unknown subjects. We use normalized features and a similarity function to match a new subject with similar subjects, for which classifiers have been previously trained. These classifiers are then used in a weighted voting system to detect workload for an unknown subject. For real-time workload classification, our methods performs at 70.4% accuracy. Higher accuracy of 76.8% can be achieved in an offline classification setting.

10:30 - 12:30
ETRA Session 1: Cognition

Note

Correlation Between Gaze and Hovers During Decision-Making Interaction

Pierre Weill-Tessier (Lancaster University);
Hans Gellersen (Lancaster University)

Taps only consist of a small part of the manual input when interacting with touch-enabled surfaces. Indeed, how the hand behaves in the hovering space is informative of what the user intends to do. In this article, we present a data collection related to hand and eye motion. We tailored a kiosk-like system to record participants' gaze and hand movements. We specifically designed a memory game to detect the decision-making process users may face. Our data collection comprises of 177 trials from 71 participants. Based on a hand movement classification, we extracted 16588 hovers. We study the gaze behaviour during hovers, and we found out that the distance between gaze and hand depends on the target's location on the screen. We also showed how indecision can be deducted from this distance.

Paper

A system to determine if learners know the divisibility rules and apply them correctly

Pieter PH Potgieter; Pieter Blignaut (University of the Free State)

Mathematics teachers may find it challenging to manage the learning that takes place in learners' minds. Typical true/false or multiple choice assessments, whether in oral, written or electronic format, do not provide evidence that learners applied the correct principles. A system was developed to analyse learners' gaze behaviour while they were determining whether a multi-digit dividend is divisible by a divisor. The system provides facilities for a teacher to set up tests and generate various types of quantitative and qualitative reports. The system was tested with a group of 16 learners from Grade 7 to Grade 10 in a pre-post experiment to investigate the effect of revision on their performance. It was proven that, with tests that are carefully compiled according to a set of heuristics, eye tracking can be used to determine whether learners use the correct strategy when applying divisibility rules.

10:30 - 12:30
COGAIN (Communication by Gaze Interaction) Session 1:

Advantages of Eye-Gaze over Head-Gaze-Based Selection in Virtual and Augmented Reality under Varying Field of Views
Jonas Blattgerste (Bielefeld University, CITEC, Bielefeld, NRW, Germany), Patrick Renner (Bielefeld University, CITEC, Bielefeld, NRW, Germany), Thies Pfeiffer (Bielefeld University, CITEC, Bielefeld, NRW, Germany)

(Long)

The current best practice for hands-free selection using Virtual and Augmented Reality (VR/AR) head-mounted displays is to use head-gaze for aiming and dwell-time or clicking for triggering the selection. There is an observable trend for new VR and AR devices to come with integrated eye-tracking units to improve rendering, to provide means for attention analysis or for social interactions. Eye-gaze has been successfully used for human-computer interaction in other domains, primarily on desktop computers. In VR/AR systems, aiming via eye-gaze could be significantly faster and less exhausting than via head-gaze.
To evaluate benefits of eye-gaze-based interaction methods in VR and AR, we compared aiming via head-gaze and aiming via eye-gaze. We show that eye-gaze outperforms head-gaze in terms of speed, task load, required head movement and user preference. We furthermore show that the advantages of eye-gaze further increase with larger FOV sizes.

Eye Movements and Viewer's Impressions in Response to HMD-Evoked Head Movements
Taijirou Shiraishi (Information and Communications Engineering, Tokyo Institute of Technology, Tokyo, Japan), Minoru Nakayama (Information and Communications Engineering, Tokyo Institute of Technology, Tokyo, Japan)
(Short)

The relationships between eye and head movements during the viewing of various visual stimuli using a head mounted display (HMD) and a large flat display were compared. The visual sizes of the images displayed were adjusted virtually, using an image processing technique. The negative correlations between head and eye movements in a horizontal direction were significant for some visual stimuli using an HMD and after some practice viewing images. Also, scores of two factors for subjective assessment of viewing stimuli positively correlated with horizontal head movements when certain visual stimuli were used. The result suggests that under certain conditions the viewing of tasks promotes head movements and stimulates correlational relationships between eye and head movements.

10:30 - 12:30
COGAIN (Communication by Gaze Interaction) Session 1:

3D Gaze Estimation in the Scene Volume with a Head-Mounted Eye Tracker
Carlos Elmadjian (Computer Science Department, University of Sao Paulo, Sao Paulo, SP, Brazil), Pushkar Shukla (Computer Science Department, University of California, Santa Barbara, Santa Barbara, California, United States), Antonio Diaz Tula (Computer Science Department, University of São Paulo, São Paulo, SP, Brazil), Carlos H Morimoto (Computer Science Department, University of São Paulo, São Paulo, SP, Brazil)
(Long)

Most applications involving gaze-based interaction are supported by estimation techniques that find a mapping between gaze data and corresponding targets on a 2D surface. However, in Virtual and Augmented Reality (AR) environments, interaction occurs mostly in a volumetric space, which poses a challenge to such techniques. Accurate point-of-regard (PoR) estimation, in particular, is of great importance to AR applications, since most known setups are prone to parallax error and target ambiguity. In this work, we expose the limitations of widely used techniques for PoR stimation in 3D and propose a new calibration procedure using an uncalibrated head-mounted binocular eye tracker coupled with an RGB-D camera to track 3D gaze within the scene volume. We conducted a study to evaluate our setup with real-world data using a geometric and an appearance-based method. Our results show that accurate estimation in this setting still is a challenge, though some gaze-based interaction techniques in 3D should be possible.

MovEye: Gaze Control of Video Playback
Jacek Matulewski (Instytut Fizyki, Toruń, Kujawsko-Pomorskie, Poland), Bibianna Bałaj (Faculty of Humanities , Nicolaus Copernicus University, Torun, Poland), Ewelina Maria Marek (Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Torun, Poland), Łukasz Piasecki (Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Torun, Poland), Dawid Gruszczyński (Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Torun, Poland), Mateusz Kuchta (Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Torun, Poland), Włodzisław Duch (Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Torun, Poland)
(Short)

Several methods of gaze control of video playback were implemented in MovEye application. Two versions of MovEye are ready: for watching online movies from the YouTube service and for watching movies from the files stored on local drives. We have two goals: the social one is to help people with physical disabilities to control and enrich their immediate environment; the scientific one is to compare usability of several video playback gaze control methods in case of healthy and disabled users. The aim of this paper is to present technically tested ready-to-use gaze control applications. Our next step will be conducting the accessibility and user experience (UX) tests for both healthy and disabled users. The long-time perspective of this research could lead to the implementation of gaze control in TV sets and other video playback devices.

10:30 - 12:30
COGAIN (Communication by Gaze Interaction) Session 1:

Playing Music with the Eyes Through an Isomorphic Interface
Nicola Davanzo (Department of Electrical, Computer and Biomedical Engineering, University of Pavia, Pavia, Italy), Piercarlo Dondi (CISRiC, Arvedi Laboratory of Non-Invasive Diagnostics, University of Pavia, Cremona, Italy), Mauro Mosconi (Department of Electrical, Computer and Biomedical Engineering, University of Pavia, Pavia, Italy), Marco Porta (Department of Electrical, Computer and Biomedical Engineering, University of Pavia, Pavia, Italy)
(Short)

Playing music with the eyes is a challenging task. In this paper, we propose a virtual digital musical instrument, usable by both motor-impaired and able-bodied people, controlled through an eye tracker and a "switch". Musica lly speaking, the layout of the graphical interface is isomorphic, since the harmonic relations between notes have the same geometrical shape regardless of the key signature of the music piece. Four main design principles guided our choices, namely: (1) Minimization of eye movements, especially in case of large note intervals; (2) Use of a grid layout where "nodes" (key are connected each other through segments (employed as guides for the gaze); (3) No need for smoothing filters or time thresholds; and (4) Strategic use of color to facilitate gaze shifts. Preliminary tests, also involving another eye-controlled musical instrument, have shown that the developed system allows "correct" execution of music pieces even when characterized by complex melodies.

10:30 - 12:30
COGAIN (Communication by Gaze Interaction) Session 1:

Context Switching Eye Typing Using Dynamic Expanding Targets
Carlos H Morimoto (Computer Science Department, University of São Paulo, São Paulo, SP, Brazil), José Antonio Tula Leyva (Computer Science Department, University of São Paulo, São Paulo, SP, Brazil), Antonio Diaz Tula (Computer Science Department, University of São Paulo, São Paulo, SP, Brazil)
(Long)

Text entry by gazing on a virtual keyboard (also known as eye typing) is an important component of any gaze communication system. One of the main challenges for efficient communication is how to avoid unintended key selections due to the Midas' touch problem. The most common selection technique by gaze is dwelling. Though easy to learn, long dwell-times slows down the communication, and short dwells are prone to error. Context switching (CS) is a faster and more comfortable alternative, but the duplication of contexts takes a lot of screen space. In this paper we introduce two new CS designs using dynamic expanding targets that are more appropriate when a reduced interaction window is required. We compare the performance of the two new designs with the original CS design using QWERTY layouts as contexts. Our results with 6 participants typing with the 3 keyboards show that the use of smaller size layouts with dynamic expanding targets are as accurate and comfortable as the larger QWERTY layout, though providing lower typing speeds.

13:30 - 15:30
ETRA Session 2: Fundamental Eye Tracking

Session Chair: Thies Pfeiffer

Paper **Supervised Descent Method (SDM) applied to accurate pupil detection in off-the-shelf eye tracking systems**

Andoni Larumbe (Public University of Navarre); Arantxa Villanueva (Public University of Navarre); Rafael Cabeza (Public University of Navarre)

The precise detection of pupil/iris center is key to estimate gaze accurately. This fact becomes specially challenging in low cost frameworks in which the algorithms employed for high performance systems fail. In the last years an outstanding effort has been made in order to apply training-based methods to low resolution images. In this paper, Supervised Descent Method (SDM) is applied to GI4E database. The 2D landmarks employed for training are the corners of the eyes and the pupil centers. In order to validate the algorithm proposed, a cross validation procedure is performed. The strategy employed for the training allows us to affirm that our method can potentially outperform the state of the art algorithms applied to the same dataset in terms of 2D accuracy. The promising results encourage to carry on in the study of training-based methods for eye tracking.

Note **CBF:Circular binary features for robust and real-time pupil center detection**

Wolfgang Fuhl (Wilhelm Schickard Institut); David Geisler (University of Tuebingen); Thiago Santini (University of Tübingen); Tobias Appel (Learning, Educational Achievement, and Life Course Development); Wolfgang Rosenstiel (Wilhelm Schickard Institut); Enkelejda Kasneci (University of Tubingen)

Modern eye tracking systems rely on fast and robust pupil detection, and several algorithms have been proposed for eye tracking under real world conditions. In this work, we propose a novel binary feature selection approach that is trained by computing conditional distributions. These features are scalable and rotatable, allowing for distinct image resolutions, and consist of simple intensity comparisons, making the approach robust to different illumination conditions as well as rapid illumination changes. The proposed method was evaluated on multiple publicly available data sets, considerably outperforming state-of-the-art methods, and being real-time capable for very high frame rates. Moreover, our method is designed to be able to sustain pupil center estimation even when typical edge-detection-based approaches fail - e.g., when the pupil outline is not visible due to occlusions from reflections or eye lids / lashes. As a consequece, it does not attempt to provide an estimate for the pupil outline. Nevertheless, the pupil center suffices for gaze estimation - e.g., by regressing the relationship between pupil center and gaze point during calibration.

13:30 - 15:30
ETRA Session 2: Fundamental Eye Tracking

Paper **A novel approach to single camera, glint-free 3D eye model fitting including corneal refraction**

Kai Dierkes (Pupil Labs Research); Moritz Kassner (Pupil Labs Research); Andreas Bulling (Pupil Labs Research)

Model-based methods for glint-free gaze estimation typically infer eye pose using pupil contours extracted from eye images. Existing methods, however, either ignore or require complex hardware setups to deal with refraction effects occurring at the corneal interfaces. In this work we provide a detailed analysis of the effects of refraction in glint-free gaze estimation using a single near-eye camera, based on the method presented by [wirski and Dodgson 2013]. We demonstrate systematic deviations in inferred eyeball positions and gaze directions with respect to synthetic ground-truth data and show that ignoring corneal refraction can result in angular errors of several degrees. Furthermore, we quantify gaze direction dependent errors in pupil radius estimates. We propose a novel approach to account for corneal refraction in 3D eye model fitting and by analyzing synthetic and real images show that our new method successfully captures refraction effects and helps to overcome the shortcomings of the state of the art approach.

Note **Smooth-i: Smart Re-Calibration Using Smooth PursuitEye Movements**

Argenis Ramirez Gomez (Lancaster University); Hans Gellersen (Lancaster University)

Eye gaze for interaction is dependent on calibration. However, gaze calibration can deteriorate over time affecting the usability of the system. We propose to use motion matching of smooth pursuit eye movements and known motion on the display to determine when there is a drift in accuracy and use it as input for re-calibration. To explore this idea we developed Smooth-i, an algorithm that stores calibration points and updates them incrementally when inaccuracies are identified. To validate the accuracy of Smooth-i, we conducted a study with five participants and a remote eye tracker. A baseline calibration profile was used by all participants to test the accuracy of the Smooth-i re-calibration following interaction with moving targets. Results show that Smooth-i is able to manage re-calibration efficiently, updating the calibration profile only when inaccurate data samples are detected.

13:30 - 15:30
ETRA Session 2: Fundamental Eye Tracking

Paper **Comparison of mapping algorithms for implicit calibration using probable fixation targets**

Pawel Kasprowski (Silesian University of Technology); Katarzyna Harezlak (Silesian University of Technology)

With growing access to cheap low end eye trackers using simple web cameras, there is also a growing demand on easy and fast usage of this devices by untrained and unsupervised end users. For such users the necessity to calibrate the eye tracker prior to its first usage is often perceived as obtrusive and inconvenient. In the same time perfect accuracy is not necessary for many commercial applications. Therefore, the idea of implicit calibration attracts more and more attention. Algorithms for implicit calibration are able to calibrate the device without any active collaboration with users. Especially, a real time implicit calibration, that is able to calibrate a device on-the-fly, while a person uses an eye tracker, seems to be a reasonable solution to the aforementioned problems. The paper presents examples of implicit calibration algorithms (including their real time versions) based on the idea of probable fixation targets (PFT). The algorithms were tested during a free viewing experiment and compared to the state of the art PFT based algorithm and explicit calibration results.

Paper **Revisiting Data Normalization for Appearance-Based Gaze Estimation**

Xucong Zhang (Max Planck Institute for Informatics); Yusuke Sugano (Osaka University); Andreas Bulling (Max Planck Institute for Informatics)

Appearance-based gaze estimation is promising for unconstrained real-world settings, but the significant variability in head pose and user-camera distance poses significant challenges for training generic gaze estimators. Data normalization was proposed to cancel out this geometric variability by mapping input images and gaze labels to a normalized space. Although used successfully in prior works, the role and importance of data normalization remains unclear. To fill this gap, we study data normalization for the first time using principled evaluations on both simulated and real data. We propose a modification to the current data normalization formulation by removing the scaling factor and show that our new formulation performs significantly better (between 9.5% and 32.7%) in the different evaluation settings. Using images synthesized from a 3D face model, we demonstrate the benefit of data normalization for the efficiency of the model training. Experiments on real-world images confirm the advantages of data normalization in terms of gaze estimation performance.

13:30 - 15:30
COGAIN (Communication by Gaze Interaction) Session 2:

A Fitts' Law Study of Click and Dwell Interaction by Gaze, Head and Mouse with a Head-Mounted Display
John Paulin Hansen (Technical University of Denmark, Kgs. Lyngby, Denmark), Vijay Rajanna (Sketch Recognition Lab, Texas A&M University, College Station, Texas, United States), Scott MacKenzie (Department of Computer Science & Engineering, York University, Toronto, Ontario, Canada), Per Bækgaard (Technical University of Denmark, Kgs. Lyngby, Denmark)
(Short)

Gaze and head tracking, or pointing, in head-mounted displays enables new input modalities for point-select tasks. We conducted a Fitts' law experiment with 41 subjects comparing head pointing and gaze pointing using a 300 ms dwell (n= 22) or click (n = 19) activation, with mouse input providing a baseline for both conditions. Gaze and head pointing were equally fast but slower than the mouse; dwell activation was faster than click activation. Throughput was highest for the mouse (2.75 bits/s), followed by head pointing (2.04 bits/s) and gaze pointing (1.85 bits/s). With dwell activation, however, throughput for gaze and head pointing were almost identical, as was the effective target width (≈ 55 pixels; about 2◦) for all three input methods. Subjective feedback rated the physical workload less for gaze pointing than head pointing.

A Fitts' Law Evaluation of Gaze Input on Large Displays Compared to Touch and Mouse Inputs
Vijay Rajanna (Sketch Recognition Lab, Texas A&M University, College Station, Texas, United States), Tracy Hammond (Sketch Recognition Lab, Texas A&M University, College Station, Texas, United States)
(Short)

Gaze-assisted interaction has commonly been used in a standard desktop setting. When interacting with large displays, as new scenarios like situationally-induced impairments emerge, it is more convenient to use the gaze-based multi-modal input than other inputs. However, it is unknown as to how the gaze-based multimodal input compares to touch and mouse inputs. We compared gaze+foot multi-modal input to touch and mouse inputs on a large display in a Fitts' Law experiment that conforms to ISO 9241-9. From a study involving 23 participants, we found that the gaze input has the lowest throughput (2.33 bits/s), and the highest movement time (1.176 s) of the three inputs. In addition, though touch input involves maximum physical movements, it achieved the highest throughput (5.49 bits/s), the least movement time (0.623 s), and was the most preferred input.

13:30 - 15:30
COGAIN (Communication by Gaze Interaction) Session 2:

Content-based Image Retrieval Based On Eye-tracking
Ying Zhou (School of Electronic and Information Engineering, Soochow University, Suzhou, P.R.China), Jiajun Wang (School of Electronic and Information Engineering, Soochow University, Suzhou, P.R.China), Zheru Chi (Department of Electronic and Information Engineering, The HongKong Polytechnic University, HongKong, P.R.China)
(Long)

To improve the performance of an image retrieval system, a novel content-based image retrieval (CBIR) framework with eye tracking data based on an implicit relevance feedback mechanism is proposed in this paper. Our proposed framework consists of three components: feature extraction and selection, visual retrieval, and relevance feedback. First, by using the quantum genetic algorithm and the principle component analysis algorithm, optimal image features with 70 components are extracted. Second, a finer retrieving procedure based on multiclass support vector machine (SVM) and fuzzy c-mean (FCM) algorithm is implemented for retrieving most relevant images. Finally, a deep neural network is trained to exploit the information of the user regarding the relevance of the returned images. This information is then employed to update the retrieving point for a new round retrieval. Experiments on two databases (Corel and Caltech) show that the performance of CBIR can be significantly improved by using our proposed framework.

Beyond Gaze Cursor - Exploring Information-Based Gaze Sharing In Chat
Christian Schlösser (University of Applied Sciences and Arts, Dortmund, Germany), Linda Cedli (University of Applied Sciences and Arts, Dortmund, Germany), Benedikt Schröder (University of Applied Sciences and Arts, Dortmund, Germany), Andrea Kienle (University of Applied Sciences and Arts, Dortmund, Germany)
(Short)

Gaze sharing is found to be beneficial for computer-mediated collaboration by several studies. Usually, a coordinate-based visualization like a gaze cursor is used which helps to reduce or replace deictic expressions and thus makes gaze sharing a useful addition for tasks where referencing is crucial. But the spatial-based visualization limits its use to What-You-See-Is-What-I-See (WYSIWIS) interfaces and puts a ceiling on group size, as multiple object tracking becomes near impossible beyond dyads. In this paper, we will explore and discuss the use of gaze sharing outside the realm of WYSIWIS interfaces and dyads by replacing the gaze cursor with information-based gaze sharing in form of a reading progress bar to a chat interface. Preliminary results with triads show that historic and present information on attention and reading behavior are a useful addition to increase group awareness.

16:00 - 18:00
PETMEI (PERVASIVE EYE TRACKING AND MOBILE EYE-BASED INTERACTION) Session 1 Session Chair: Thiago Santini

Introducing I2Head Database
Ion Martinikorena, Rafael Cabeza, Arantxa Villanueva, Sonia Porta

I2Head database has been created with the aim to become an optimal reference for low cost gaze estimation. It exhibits the following outstanding characteristics: it takes into account key aspects of low resolution eye tracking technology; it combines images of users gazing at different grids of points from alternative positions with registers of user's head position and it provides calibration information of the camera and a simple 3D head model for each user.
Hardware used to build the database includes a 6D magnetic sensor and a webcam. A careful calibration method between the sensor and the camera has been developed to guarantee the accuracy of the data. Different sessions have been recorded for each user including not only static head scenarios but also controlled displacements and even free head movements. The database is an outstanding framework to test both gaze estimation algorithms and head pose estimation methods

Making stand-alone PS-OG technology tolerant to the equipment shifts
Raimondas Zemblys, Oleg Komogortsev

Tracking users' gaze in virtual reality headsets allows natural and intuitive interaction with virtual avatars and virtual objects. Moreover, a technique known as foveated rendering can help save computational resources and enable hi-resolution but lightweight virtual reality technologies. Predominantly, eye-tracking hardware in modern VR headsets consist of infrared camera(s) and LEDs. Such hardware, together with image processing software consumes a substantial amount of energy, and, provided that hi-speed gaze detection is needed, might be very expensive. A promising technique to overcome these issues is photo-sensor oculography (PS-OG), which allows eye-tracking with high sampling rate and low power consumption. However, the main limitation of the previous PS-OG systems is their inability to compensate for the equipment shifts. In this study, we employ a simple multi-layer perceptron neural network to map raw sensor data to gaze locations and report its performance for shift compensation. Modeling and evaluation is done via a simulation.

Crowdsourcing pupil annotation datasets: boundary vs. center, what performs better?
David Gil de Gómez Pérez, Matti Suokas, Roman Bednarik

Pupil-related feature detection is one of the most common approaches used in the eye-tracking literature and practice. Validation and benchmarking of the detection algorithms relies on accurate ground-truth datasets, but creating of these is costly. Many approaches have been used to obtain human based annotations. A recent proposal to obtain these work-intensive data is through a crowdsourced registration of the pupil center, in which a large number of users provide a single click to indicate the pupil center. In this paper we compare the existing approach to a method based on multiple clicks on the boundary of the pupil region, in order to determine which approach provides better results. To compare both methods, a new data collection was performed over the same image database. Several metrics were applied in order to evaluate the accuracy of the two methods.

16:00 - 18:00
ETRA Short Papers in Poster Session

[S1] **EyeMSA: Exploring Eye Movement Data with Pairwise and Multiple Sequence Alignment**
Michael Burch (Eindhoven University of Technology); Kuno Kurzhals (University of Stuttgart); Niklas Kleinhans (VISUS, University of Stuttgart); Daniel Weiskopf (VISUS)

[S2] **PuReST: Robust Pupil Tracking for Real-Time Pervasive Eye Tracking**
Thiago Santini (University of Tübingen); Wolfgang Fuhl (Wilhelm Schickard Institut); Enkelejda Kasneci (University of Tubingen)

[S3] **Sensitivity to Natural 3D Image Transformations during Eye Movements**
Maryam Keyvanara (York University); Robert Allison (York University)

[S4] **Robustness of metrics used for scanpath comparison**
Filip Dechterenko (Institute of Psychology, Czech Academy of Sciences); Jiri Lukavsky (Institute of Psychology, Czech Academy of Sciences)

[S5] **AnyOrbit: Eye-tracking for orbital navigation in virtual environments**
Demo *Benjamin Outram (Keio University Graduate School of Media Design); Yun Suen Pai (Keio University Graduate School of Media Design); Tanner Person (Keio University Graduate School of Media Design); Kouta Minamizawa (Keio University Graduate School of Media Design); Kai Kunze (Keio University)*

[S6] **Ocular reactions in response to impressions of emotion-evoking pictures**
Minoru Nakayama (Tokyo Institute of Technology)

[S7] **Image-Based Scanpath Comparison with Slit-Scan Visualization**
Maurice Koch (University of Stuttgart); Kuno Kurzhals (University of Stuttgart); Daniel Weiskopf (University of Stuttgart

[S8] **Systematic shifts of fixation disparity accompanying brightness changes**
Anke Huckauf (Ulm University)

[S9] **Pupil Responses Signal Less Inhibition for Own Relative to Other Names**
Lukas Greiter (Ulm University); Christoph Strauch (Ulm University); Anke Huckauf (Ulm University)

[S10] **Wearable Eye Tracker Calibration at Your Fingertips**
Mihai Bâce (Department of Computer Science); Sander Staal (Department of Computer Science); Gábor Sörös (Department of Computer Science)

[S11] **How many words is a picture worth? Attention allocation on thumbnails versus title text regions**
Chaitra Yangandul (University of Florida); Sachin Paryani (CISE); Madison Le (Google); Eakta JAIN (University of Florida)

16:00 - 18:00
ETRA Short Papers in Poster Session

[S12] **Useful Approaches to Exploratory Analysis of Gaze Data: Enhanced Heatmaps, Cluster Maps, and Transition Maps**
Poika Isokoski (University of Tampere); Jari Kangas (University of Tampere); Päivi Majaranta (University of Tampere)

[S13] **Pupil Size as an Indicator of Visual-motor Workload and Expertise in Microsurgical Training Tasks**
Roman Bednarik (University of Eastern Finland); Piotr Bartczak (University of Eastern Finland); Hana Vrzakova (University of Eastern Finland); Jani Koskinen (University of Eastern Finland); Antti-Pekka Elomaa (Kuopio University Hospital); Antti Huotarinen (Kuopio University Hospital); David Gil de Gómez Pérez (University of Eastern Finland); Mikael von Und Zu Fraunberg (Neurosurgery)

[S14] **DeepComics: Saliency estimation for comics**
Kévin BANNIER (Univ Rennes, CNRS, Inria, IRISA); Eakta JAIN (University of Florida); OLIVIER LE MEUR (Univ Rennes, CNRS, Inria, IRISA)

[S15] **A Visual Comparison of Gaze Behavior from Pedestrians and Cyclists**
Mathias Trefzger (Karlsruhe University of Applied Sciences); Tanja Blascheck (INRIA); Michael Raschke (Blickshift GmbH); Sarah Hausmann (Karlsruhe University of Applied Sciences); Thomas Schlegel (Karlsruhe University of Applied Sciences)

[S16] **Binocular model-based gaze estimation with a camera and a single infrared light source**
Laura Sesma-Sanchez (Universidad Pública de Navarra); Hansen Dan (IT University of Copenhagen)

[S17] **GazeCode: open-source software for manual mapping of mobile eye-tracking data**
Jeroen S. Benjamins (Utrecht University); Roy S. Hessels (Utrecht University); Ignace T.C. Hooge (Utrecht University)

[S18] **Relating eye-tracking measures with changes in knowledge on search tasks**
Nilavra Bhattacharya (University of Texas at Austin); Jacek Gwizdka (University of Texas at Austin)

[S19] **Fixation-Indices based Correlation between Text and Image Visual Features of Webpages**
Sandeep Vidyapu (Indian Institute of Technology Guwahati); V Vijaya Saradhi (IIT Guwahati); Samit Bhattacharya (Indian Institute of Technology Guwahati)

[S20] **Development and Evaluation of a Gaze Feedback System Integrated into EyeTrace**
Kai Otto (University of Tuebingen); Nora Castner (University of Tübingen); David Geisler (University of Tuebingen); Enkelejda Kasneci (University of Tubingen)

[S21] **Rapid Alternating Saccade Training**
Brent D. Parsons (SISSA); Richard Ivry (UC Berkeley)

16:00 - 18:00
ETRA Short Papers in Poster Session

[S22] **Hidden Pursuits: Evaluating Gaze-selection via Pursuits when the Stimulus Trajectory is Partially Hidden**
Thomas Mattusch (LMU Munich); Mahsa Mirzamohammad (University of Jyväskylä); Mohamed Khamis (LMU Munich); Andreas Bulling (Max Planck Institute for Informatics); Florian Alt (LMU Munich)

[S23] **CBF:Circular binary features for robust and real-time pupil center detection**
Wolfgang Fuhl (Wilhelm Schickard Institut); David Geisler (University of Tuebingen); Thiago Santini (University of Tübingen); Tobias Appel (Learning, Educational Achievement, and Life Course Development); Wolfgang Rosenstiel (Wilhelm Schickard Institut); Enkelejda Kasneci (University of Tubingen)

[S24] **SLAM-based Localization of 3D Gaze using a Mobile Eye Tracker**
Haofei Wang (HKUST); Jimin Pi (Hong Kong University of Science and Technolody); Tong Qin (HKUST); Shaojie Shen (HKUST); Bertram E. Shi (Hong Kong University of Science and Technology)

[S25] **Implicit user calibration for gaze-tracking systems using averaged saliency map around the optical axis of the eye**
Mamoru Hiroe (Kobe University); Michiya Yamamoto (Kwansei Gakuin University); Takashi Nagamatsu (Kobe University)

[S26] **BORE: Boosted-oriented edge optimization for robust, real time remote pupil center detection**
Wolfgang Fuhl (Wilhelm Schickard Institut); Dr. Shahram Eivazi (Eberhard Karls University); Benedikt Werner Hosp (Institute of Sports Science); Anna Eivazi (Wilhelm Schickard Institut); Wolfgang Rosenstiel (Wilhelm Schickard Institut); Enkelejda Kasneci (University of Tubingen)

[S27] **Development of diagnostic performance & visual processing in different types of radiological expertise**
Pawel Kasprowski (Silesian University of Technology); Katarzyna Harezlak (Silesian University of Technology); Sabina Kasprowska (District Hospital of Orthopedics and Trauma Surgery)

[S28] **Suitability of calibration polynomials for eye-tracking data with simulated fixation inaccuracies**
William Rosengren (Department of Biomedical Engineering); Marcus Nyström (Lund University Humanities Lab); Bjorn Hammar (Department of Clinical Sciences); Martin Stridh (Department of Biomedical Engineering)

[S29] **Training facilitates cognitive control on pupil dilation**
Jan Ehlers (Bauhaus University Weimar); Christoph Strauch (Ulm University); Anke Huckauf (Uni University)

[S30] **Microsaccade detection using pupil and corneal reflection signals**
Diederick C. Niehorster (Lund University); Marcus Nyström (Lund University Humanities Lab)

16:00 - 18:00
ETRA Short Papers in Poster Session

[S31] **An Eye Gaze Model for Seismic Interpretation Support**
Vagner Figueredo de Santana (IBM Research); Juliana Jansen Ferreira (IBM Research); Rogerio de Paula (IBM Research); Renato Cerqueira (IBM Research)

[S32] **Towards Using the Spatio-temporal Properties of Eye Movements to Classify Visual Field Defects**
Alessandro Grillini (University Medical Center Groningen); Daniel Ombelet (University of Groningen); Rijul Saurabh Soans (Indian Institute of Technology - Delhi); Frans W Cornelissen (University Medical Center Groningen)

[S33] **Scene perception while listening to music: an eye-tracking study**
Jan Petruzalek (University of Hradec Králové); Denis Šefara (University of Hradec Králové); Marek Franek (University of Hradec Králové); Martin Kabeláč (University of Hradec Králové)

[S34] **Smooth-i: Smart Re-Calibration Using Smooth Pursuit Eye Movements**
Argenis Ramirez Gomez (Lancaster University); Hans Gellersen (Lancaster University)

[S35] **Predicting observer's task from eye movement patterns during motion image analysis**
Jutta Hild (Fraunhofer IOSB); Christian Kühnle (Fraunhofer IOSB); Michael Voit (Fraunhofer IOSB); Jürgen Beyerer (Fraunhofer IOSB)

[S36] **AutoPager: Exploiting Change Blindness for Gaze-Assisted Reading**
Andrew D Wilson (Microsoft Research); Shane Williams (Microsoft)

[S37] **Evaluating Similarity Measures for Gaze Patterns in the Context of Representational Competence in Physics Education**
Seyyed Saleh Mozaffari Chanijani (German Research Center for Artificial Intelligence); Pascal Klein (TU Kaiserslautern / Physics); Jouni Viiri (University of Jyväskylä); Sheraz Ahmed (DFKI gmbH); Jochen Kuhn (Technische Universität Kaiserslautern); Andreas Dengel (German Research Center for Artificial Intelligence)

[S38] **Towards Gaze-Based Quantification of the Security of Graphical Authentication Schemes**
Christina Katsini (University of Patras); George E Raptis (University of Patras); Christos Fidas (University of Patras); Nikolaos Avouris (University of Ptras)

[S39] **Correlation Between Gaze and Hovers During Decision-Making Interaction**
Pierre Weill-Tessier (Lancaster University); Hans Gellersen (Lancaster University)

16:00 - 18:00
ETRA Videos

[V1] **Head and Gaze Control of a Telepresence Robot With an HMD**
Sigrid Klerke (EyeJustRead.com); Janus Askø Madsen (EyeJustRead.com); Emil Juul Jacobsen (EyeJustRead.com); John Paulin Paulin Hansen (Technical University of Denmark)

[V2] **Developing Photo-Sensor Oculography (PS-OG) system for Virtual Reality headsets**
Raimondas Zemblys (Michigan State University); Oleg Komogortsev (Michigan State University)

[V3] **Automatic mapping of gaze position coordinates of eye-tracking glasses video on a common static reference image**
Adam Bykowski (Poznan Supercomputing and Networking Center); Szymon Kupiński (Poznan Supercomputing and Networking Center))

[V4] **Substantiating Reading Teachers with Scanpaths**
Sigrid Klerke (EyeJustRead.com); Janus Askø Madsen (EyeJustRead.com); Emil Juul Jacobsen (EyeJustRead.com); John Paulin Paulin Hansen (Technical University of Denmark)

[V5] **Tracing Gaze-Following Behavior in Virtual Reality Using Wiener-Granger Causality**
Marius Rubo (Department of Psychology); Matthias Gamer (University of Würzburg)

[V6] **Semantic Fovea: Real-time annotation of ego-centric videos with gaze context**
Chaiyawan Auepanwiriyakul (Imperial College London); John Alexander Harston (Imperial College London); Pavel Orlov (Imperial College London); Ali Shafti (Imperial College London); Aldo Faisal (Imperial College London)

[V7] **Hands-Free Web Browsing: Enriching the User Experience with Gaze and Voice Modality**
Korok Sengupta (University of Koblenz-Landau); Min Ke (University of Koblenz-Landau); Raphael Menges (University of Koblenz-Landau); Chandan Kumar (University of Koblenz-Landau); Steffen Staab (University of Koblenz-Landau)

[V8] **Mobile Consumer Shopping Journey in Fashion Retail: Eye Tracking Mobile Apps and Websites**
Zofija Tupikovskaja-Omovie (Manchester Metropolitan University)

[V9] **EyeMR - Low-cost Eye-Tracking for Rapid-prototyping in Head-mounted Mixed Reality**
Tim Claudius Stratmann (University of Oldenburg); Uwe Gruenefeld (University of Oldenburg); Susanne Boll (University of Oldenburg)

[V10] **A Gaze-Contingent Intention Decoding Engine for human augmentation**
Pavel Orlov (Imperial College London); Ali Shafti (Imperial College London); Chaiyawan Auepanwiriyakul (Imperial College London); Noyan Songur (Imperial College London); Aldo Faisal (Imperial College London)

16:00 - 18:00
ETRA Videos

[V11] **Use of Attentive Information Dashboards to Support Task Resumption in Working Environments**
Peyman Toreini (Karlsruhe Institute of Technology); Moritz Langner (Karlsruhe Institute of Technology); Alexander Maedche (Karlsruhe Institute of Technology (KIT))

[V12] **EyeMic: an eye tracker for surgical microscope**
Shahram Eivazi (University of Tubingen); Maximilian Maurer (University of Tubingen)

[V13] **Real-time gaze transition entropy**
Islam A. Ebeid (University of Texas at Austin); Jacek Gwizdka (University of Texas at Austin)

[V14] **Modeling Corneal Reflection for Eye-tracking Considering Eyelid Occlusion**
Michiya Yamamoto (Kwansei Gakuin University); Ryoma Matsuo (Kwansei Gakuin University); Satoshi Fukumori (Kwansei Gakuin University); Takashi Nagamatsu (Kobe University)

[V15] **Enhanced Representation of Web Pages for Usability Analysis with Eye Tracking**
Raphael Menges (University of Koblenz-Landau); Hanadi Tamimi (University of Koblenz-Landau); Chandan Kumar (University of Koblenz-Landau); Tina Walber (EYEVIDO GmbH); Christoph Schaefer (EYEVIDO GmbH); Steffen Staab (University of Koblenz-Landau)

[V16] **Self-made mobile gaze tracking for group studies**
Miika Toivanen (University of Helsinki); Visajaani Salonen (University of Helsinki); Markku Hannula (University of Helsinki)

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SR Research welcomes you to ETRA 2018. Our EyeLink systems continue to set the standard for eye tracking on every dimension, providing reliable, high-precision, high-speed (up to 2000 Hz) data for participants of all ages. Our powerful and intuitive software makes collecting and analyzing eye movement data simpler than ever before. Our recently updated Screen Recorder software allows users to make a video screen capture of whatever is happening on a computer with gaze position overlaid - perfect for tests of participant behavior when interacting with software/applications or when navigating the web. Data Viewer allows users to watch video playbacks, generate heat maps, draw dynamic areas of interest, and easily extract summary data. With the world's best technical specifications, powerful software, and unparalleled support service, SR Research enables researchers to achieve their eye tracking goals. Drop by the booth and discuss our latest hardware and software additions.

16:00 - 18:00
ETRA Demos

[D1] **An Implementation of Eye Movement-Driven Biometrics in Virtual Reality**
Dillon J Lohr (Texas State University); Samuel-Hunter Berndt (Michigan State University); Oleg Komogortsev (Michigan State University)

[D2] **AnyOrbit: Orbital navigation in virtual environments with eye-tracking**
Benjamin Outram (Keio University Graduate School of Media Design); Yun Suen Pai (Keio University Graduate School of Media Design); Tanner Person (Keio University Graduate School of Media Design); Kouta Minamizawa (Keio University Graduate School of Media Design); Kai Kunze (Keio University Graduate School of Media Design)

[D3] **Robust Marker Tracking for Mapping Mobile Eye Tracking Data**
Iyad Aldaqre (SR LABS Srl); Roberto Delfiore (SR LABS Sr)

[D4] **Deep Learning vs. Manual Annotation of Eye Movements**
Mikhail Startsev (Technical University of Munich); Ioannis Agtzidis (Technical University of Munich); Michael Dorr (Technical University Munich)

[D5] **A Gaze Gesture-based Paradigm for Situational Impairments, Accessibility, and Rich Interactions**
Vijay Rajanna (Texas A&M University); Tracy Hammond (Texas A&M University)

[D6] **New Features of ScanGraph - a Tool for Revealing Participants' Strategy from Eye-movement Data**
Stanislav Popelka (Palacký University Olomouc); Jitka Dolezalova (Palacký University Olomouc); Marketa Beitlova (Palacký University Olomouc)

[D7] **A Visual Comparison of Gaze Behavior from Pedestrians and Cyclists**
Mathias Trefzger (Karlsruhe University of Applied Sciences); Tanja Blascheck (Inria Saclay); Michael Raschke (Blickshift GmbH); Sarah Hausmann (Karlsruhe University of Applied Sciences); Thomas Schlegel (Karlsruhe University of Applied Sciences)

[D8] **iTrace: Eye Tracking Infrastructure for Development Environments**
Drew T. Guarnera (Kent State University); Corey A. Bryant (Kent State University); Ashwin Mishra (Youngstown State University); Jonathan Maletic (Kent State University); Bonita Sharif (Youngstown State University)

[D9] **An Inconspicuous and Modular Head-Mounted Eye Tracker**
Shahram Eivazi (University of Tubingen); Thomas C Kübler (University of Tubingen); Thiago Santini (University of Tubingen); Enkelejda Kasneci (University of Tubingen)

10:30 - 12:30 ETRA Session 3: Digital Interactions

Session Chair: Andrew Duchowski

Paper **Leveraging Eye-gaze and Time-series Features to Predict User Interests and Build a Recommendation Model for Visual Analysis**

Nelson J. S. Silva (Know-center GmbH); Tobias Schreck (Institute of Computer Graphics and Knowledge Visualisation (CGV)); Eduardo Veas (Know-center GmbH); Vedran Sabol (Know-center GmbH); Eva Eggeling (Fraunhofer Austria Research GmbH); Dieter W. Fellner (Fraunhofer IGD Germany)

We developed a new concept to improve the efficiency of visual analysis through visual recommendations. It uses a novel eye-gaze based recommendation model that aids users in identifying interesting time-series patterns. Our model combines time-series features and eye-gaze interests, captured via an eye-tracker. Mouse selections are also considered. The system provides an overlay visualization with recommended patterns, and an eye-history graph, that supports the users in the data exploration process. We conducted an experiment with 5 tasks where 30 participants explored sensor data of a wind turbine. This work presents results on pre-attentive features, and discusses the precision/recall of our model in comparison to final selections made by users. Our model helps users to efficiently identify interesting time-series patterns.

Paper **Gaze and head pointing for hands-free text entry: Applicability to ultra-small virtual keyboards**

Julia Kuosmanen (University of Tampere); Oleg Spakov (University of Tampere); Outi Tuisku (Lappeenranta University of Technology); Matthew Turk (UC Santa Barbara); Veikko Surakka (University of Tampere)

With the proliferation of small-screen computing devices, there has been a continuous trend in reducing the size of interface elements. In virtual keyboards, this allows for more characters in a layout and additional function widgets. However, vision-based interfaces (VBIs) have only been investigated with large (e.g., full-screen) keyboards. To understand how key size reduction affects the accuracy and speed performance of text entry VBIs, we evaluated gaze-controlled VBI (g-VBI) and head-controlled VBI (h-VBI) with unconventionally small (0.4°, 0.6°, 0.8° and 1°) keys. Novices (N = 26) yielded significantly more accurate and fast text production with h-VBI than with g-VBI, while the performance of experts (N = 12) for both VBIs was nearly equal when a 0.8-1° key size was used. We discuss advantages and limitations of the VBIs for typing with ultra-small keyboards and emphasize relevant factors for designing such systems.

10:30 - 12:30
ETRA Session 3: Digital Interactions

Paper **Gaze Typing in Virtual Reality: Impact of Keyboard Design, Selection Method, and Motion**

Vijay Rajanna (Texas A&M University); John Paulin Hansen (Technical University of Denmark)

Gaze tracking in virtual reality (VR) allows for hands-free text entry, but it has not yet been explored. We investigate how the keyboard design, selection method, and motion in the field of view may impact typing performance and user experience. We present two studies of people (n = 32) typing with gaze+dwell and gaze+click inputs in VR. In study 1, the typing keyboard was flat and within-view; in study 2, it was larger-than-view but curved. Both studies included a stationary and a dynamic motion conditions in the user's field of view. Our findings suggest that 1) gaze typing in VR is viable but constrained, 2) the users perform best (10.15 WPM) when the entire keyboard is within-view; the larger-than-view keyboard (9.15 WPM) induces physical strain due to increased head movements, 3) motion in the field of view impacts the user's performance: users perform better while stationary than when in motion, and 4) gaze+click is better than dwell only (fixed at 550 ms) interaction.

Paper **The Eye of the Typer: A Benchmark and Analysis of Gaze Behavior during Typing**

Alexandra Papoutsaki (Pomona College); Aaron Gokaslan (Brown University); James Tompkin (Brown University); Yuze He (Brown University); Jeff Huang (Brown University)

We examine the relationship between eye gaze and typing, focusing on the differences between touch and non-touch typists. To enable typing-based research, we created a 51-participant benchmark dataset for user input across multiple tasks, including user input data, screen recordings, webcam video of the participant's face, and eye tracking positions. There are patterns of eye movements that differ between the two types of typists, representing glances at the keyboard, which can be used to identify touch-typed strokes with 92% accuracy. Then, we relate eye gaze with cursor activity, aligning both pointing and typing to eye gaze. One demonstrative application of the work is in extending WebGazer, a real-time web-browser-based webcam eye tracker. We show that incorporating typing behavior as a secondary signal improves eye tracking accuracy by 16% for touch typists, and 8% for non-touch typists.

10:30 - 12:30
ETRA Session 3: Digital Interactions

Note **Towards Gaze-Based Quantification of the Security of Graphical Authentication Schemes**

Christina Katsini (University of Patras); George E Raptis (University of Patras); Christos Fidas (University of Patras); Nikolaos Avouris (University of Patras)

In this paper, we introduce a two-step method for estimating the strength of user-created graphical passwords based on the eye-gaze behaviour during password composition. First, the individuals' gaze patterns, represented by the unique fixations on each area of interest (AOI) and the total fixation duration per AOI, are calculated. Second, the gaze-based entropy of the individual is calculated. To investigate whether the proposed metric is a credible predictor of the password strength, we conducted two feasibility studies. Results revealed a strong positive correlation between the strength of the created passwords and the gaze-based entropy. Hence, we argue that the proposed gaze-based metric allows for unobtrusive prediction of the strength of the password a user is going to create and enables intervention to the password composition for helping users create stronger passwords.

Paper Video **Enhanced Representation of Web Pages for Usability Analysis with Eye Tracking**

Raphael Menges (University of Koblenz-Landau); Hanadi Tamimi (University of Koblenz-Landau); Chandan Kumar (University of Koblenz-Landau); Tina Walber (EYEVIDO GmbH); Christoph Schaefer (EYEVIDO GmbH); Steffen Staab (University of Koblenz-Landau)

Eye tracking as a tool to quantify user attention plays a major role in research and application design. For Web page usability, it has become a prominent measure to assess which sections of a Web page are read, glanced or skipped. Such assessments primarily depend on the mapping of gaze data to a Web page representation. However, current representation methods, a virtual screenshot of the Web page or a video recording of the complete interaction session, suffer either from accuracy or scalability issues. We present a method that identifies fixed elements on Web pages and combines user viewport screenshots in relation to fixed elements for an enhanced representation of the page. We conducted an experiment with 10 participants and the results signify that analysis with our method is more efficient than a video recording, which is an essential criterion for large scale Web studies.

10:30 - 12:30
PETMEI (PERVASIVE EYE TRACKING AND MOBILE EYE-BASED INTERACTION) Session 2 Session Chair: Enkelejda Kasneci

Gaze-based Interest Detection on Newspaper Articles
Ms Soumy Jacob, Shoya Ishimaru, Syed Saqib Bukhari, Andreas Dengel

Eye tracking measures have been used to recognize cognitive states involving mental workload, comprehension, and self-confidence in the task of reading. In this paper, we present how these measures can be used to detect the interest of a reader. From the reading behavior of 13 university students on 18 newspaper articles, we have extracted eye tracking measures to detect which documents each participant finds interesting or uninteresting. We have classified their interests into four classes with an accuracy of 44% using eye movements, and it has increased to 62% if a survey about subjective comprehension is included. This research can be incorporated in the real-time prediction of a user's interest while reading, for the betterment of future designs of human-document interaction.

The Art of Pervasive Eye Tracking: Unconstrained Eye Tracking in the Austrian Gallery Belvedere
Thiago Santini, Hanna Brinkmann, Luise Reitstätter, Helmut Leder, Raphael Rosenberg, Wolfgang Rosenstiel, Enkelejda Kasneci

Pervasive mobile eye tracking provides a rich data source to investigate human natural behavior, providing a high degree of ecological validity in natural environments. However, challenges and limitations intrinsic to unconstrained mobile eye tracking makes its development and usage to some extent an art. Nonetheless, researchers are pushing the boundaries of this technology to help assess museum visitors' attention not only between the exhibited works, but also within particular pieces, providing significantly more detailed insights than traditional timing-and-tracking or external observer approaches. In this paper, we present in detail the eye tracking system developed for a large scale fully-unconstrained study in the Austrian Gallery Belvedere, providing useful information for eye-tracking system designers. Furthermore, the study is described, and we report on usability and real-time performance metrics. Our results suggest that, although the system is comfortable enough, further eye tracker improvements are necessary to make it less conspicuous. Additionally, real-time accuracy already suffices for simple applications such as audio guides for the majority of users even in the absence of eye-tracker slippage compensation.

10:30 - 12:30
PETMEI (PERVASIVE EYE TRACKING AND MOBILE EYE-BASED INTERACTION) Session 2

Eye tracking in naturalistic badminton play – comparing visual gaze pattern strategy of professional and amateur players
Nithiya Shree Uppara, Aditi Ashutosh Mavalankar, Kavita Vemuri

A professional player's expertise rests on the ability to predict action by optimally extracting the opponent's postural cues. Eye tracking (head-mounted system) data in a naturalistic singles badminton play was collected from one professional world-ranked player facing five amateur players (10 serves or 50 trials) and two amateurs playing against four other amateur players each (10 serves or 80 trials). The visual gaze on the opponent body, segregated into 3 areas-of-interest covering the feet, face/torso, and hand/racket of the opponent and the shuttle, was analysed for a) the period just before the serve, b) receiving the serve and c) the entire rally. The comparative analysis shows the first area-of interest for professional player as the opponent's feet while executing the serve and the hand/racket when receiving a serve. Whereas, the amateur players show no particular strategy of fixation location either for the serve task or while facing a serve. The average fixation duration (just before serve) for the professional was 0.96s and for the amateurs it was 1.48s. The findings highlight the differences in the postural cue considered important and the preparatory time in professional and amateur players. We believe, analytical models from dynamic gaze behavior in naturalistic game conditions as applied in this study can be used for enhancing perceptual-cognitive skills during training.

13:30 - 15:30 Session Chair: Hans Gellersen
ETRA Session 4: Mobile Eye Tracking

Paper **Predicting the Gaze Depth in Head-mounted Displays using Multiple Feature Regression**

Martin Weier (Institute of Visual Computing); Thorsten Roth (Bonn-Rhein-Sieg University of Applied Sciences); André Hinkenjann (University of Applied Sciences Bonn-Rhein-Sieg); Philipp Slusallek (Saarland University)

Head-mounted displays (HMDs) with integrated eye trackers have opened up a new realm for gaze-contingent rendering. The accurate estimation of gaze depth is essential when modeling the optical capabilities of the eye. Most recently multifocal displays are gaining importance, requiring focus estimates to control displays or lenses. Deriving the gaze depth solely by sampling the scene's depth at the point-of-regard fails for complex or thin objects as eye tracking is suffering from inaccuracies. Gaze depth measures using the eye's vergence only provide an accurate depth estimate for the first meter. In this work, we combine vergence measures and multiple depth measures into feature sets. This data is used to train a regression model to deliver improved estimates. We present a study showing that using multiple features allows for an accurate estimation of the focused depth (MSE<0.1m) over a wide range (first 6m).

Paper **Capturing Real-World Gaze Behaviour: Live and Unplugged**

Karishma Singh (University of Manitoba); Mahmoud Kalash (University of Manitoba); Neil Bruce (Ryerson University)

Understanding human gaze behaviour has benefits from scientific understanding to many application domains. Current practices constrain possible use cases, requiring experimentation restricted to a lab setting or controlled environment. In this paper, we demonstrate a flexible unconstrained end-to-end solution that allows for collection and analysis of gaze data in real-world settings. To achieve these objectives, rich 3D models of the real world are derived along with strategies for associating experimental eye-tracking data with these models. In particular, we demonstrate the strength of photogrammetry in allowing these capabilities to be realized, and demonstrate the first complete solution for 3D gaze analysis in large-scale outdoor environments using standard camera technology without fiducial markers. The paper also presents techniques for quantitative analysis and visualization of 3D gaze data. As a whole, the body of techniques presented provides a foundation for future research, with new opportunities for experimental studies and computational modeling efforts.

13:30 - 15:30
ETRA Session 4: Mobile Eye Tracking

Paper **Learning to Find Eye Region Landmarks for Remote Gaze Estimation in Unconstrained Settings**

Seonwook Park (ETH Zurich); Xucong Zhang (Max Planck Institute for Informatics); Andreas Bulling (Max Planck Institute for Informatics); Otmar Hilliges (ETH Zurich)

Conventional feature-based and model-based gaze estimation methods have proven to perform well in settings with controlled illumination and specialized cameras. In unconstrained real-world settings, however, such methods are surpassed by recent appearance-based methods due to difficulties in modeling factors such as illumination changes and other visual artifacts. We present a novel learning-based method for eye region landmark localization that enables conventional methods to be competitive to latest appearance-based methods. Despite having been trained exclusively on synthetic data, our method exceeds the state of the art for iris localization and eye shape registration on real-world imagery. We then use the detected landmarks as input to iterative model-fitting and lightweight learning-based gaze estimation methods. Our approach outperforms existing model-fitting and appearance-based methods in the context of person-independent and personalized gaze estimation.

Note **Wearable Eye Tracker Calibration at Your Fingertips**

Mihai Bâce (Department of Computer Science); Sander Staal (Department of Computer Science); Gábor Sörös (Department of Computer Science)

Common calibration techniques for head-mounted eye trackers rely on markers or an additional person to assist with the procedure. This is a tedious process and may even hinder some practical applications. We propose a novel calibration technique which simplifies the initial calibration step for mobile scenarios. To collect the calibration samples, users only have to point with a finger to various locations in the scene. Our vision-based algorithm detects the users' hand and fingertips which indicate the users' point of interest. This eliminates the need for additional assistance or specialized markers. Our approach achieves comparable accuracy to similar marker-based calibration techniques and is the preferred method by users from our study. The implementation is openly available as a plugin for the open-source Pupil eye tracking platform.

13:30 - 15:30
ETRA Session 4: Mobile Eye Tracking

Paper **Fixation Detection for Head-Mounted Eye Tracking Based on Visual Similarity of Gaze Targets**

Julian Steil (Max Planck Institute for Informatics); Michael Xuelin Huang (Max Planck Institute for Informatics); Andreas Bulling (Max Planck Institute for Informatics)

Fixations are widely analysed in human vision, gaze-based interaction, and experimental psychology research. However, robust fixation detection in mobile settings is profoundly challenging given the prevalence of user and gaze target motion. These movements feign a shift in gaze estimates in the frame of reference defined by the eye tracker's scene camera. To address this challenge, we present a novel fixation detection method for head-mounted eye trackers. Our method exploits that, independent of user or gaze target motion, target appearance remains about the same during a fixation. It extracts image information from small regions around the current gaze position and analyses the appearance similarity of these gaze patches across video frames to detect fixations. We evaluate our method using fine-grained fixation annotations on a five-participant indoor dataset (MPIIEgoFixation) with more than 2,300 fixations in total. Our method outperforms commonly used velocity- and dispersion-based algorithms, which highlights its significant potential to analyse scene image information for eye movement detection.

Paper **Error-Aware Gaze-Based Interfaces for Robust Mobile Gaze Interaction**

Michael Barz (German Research Center for Artificial Intelligence (DFKI)); Florian Daiber (German Research Center for Artificial Intelligence (DFKI)); Daniel Sonntag (German Research Center for Artificial Intelligence (DFKI)); Andreas Bulling (Max Planck Institute for Informatics)

Gaze estimation error can severely hamper usability and performance of mobile gaze-based interfaces given that the error varies constantly for different interaction positions. In this work, we explore error-aware gaze-based interfaces that estimate and adapt to gaze estimation error on-the-fly. We implement a sample error-aware user interface for gaze-based selection and different error compensation methods: a naïve approach that increases component size directly proportional to the absolute error, a recent model by Feit et al. that is based on the two-dimensional error distribution, and a novel predictive model that shifts gaze by a directional error estimate. We evaluate these models in a 12-participant user study and show that our predictive model significantly outperforms the others in terms of selection rate, particularly for small gaze targets. These results underline both the feasibility and potential of next generation error-aware gaze-based user interfaces.

13:30 - 15:30
ETVIS (Eye Tracking and Visualization)
Session 1: Visualization

Session Chair: Kuno Kurzhals

Intuitive Visualization Technique to Support Eye Tracking Data Analysis: A User-Study
Vsevolod Peysakhovich, Christophe Hurter

While fixation distribution is conventionally visualized using heat maps, there is still a lack of a commonly accepted technique to visualize saccade distributions. Inspired by wind maps and the Oriented Line Integral Convolution (OLIC) technique, we visualize saccades by drawing ink droplets which follow the direction indicated by a flow direction map. This direction map is computed using a kernel density estimation technique over the tangent directions to each saccade gaze point. The image is further blended with the corresponding heat map. It results in an animation or a static image showing main directions of the transitions between different areas of interest. We also present results from a web-based user study where naive non-expert users where asked to identify the direction of the flow and simple patterns. The results showed that these visualizations can successfully be used to support visual analysis of the eye-tracking data. It also showed that the use of animation allows to ease the task and to improve the performance.

Multiscale Scanpath Visualization and Filtering
Nils Rodrigues, Rudolf Netzel, Joachim Spalink, Daniel Weiskopf

The analysis of eye-tracking data can be very useful when evaluating controlled user studies. To support the analysis in a fast and easy fashion, we have developed a web-based framework for a visual inspection of eye-tracking data and a comparison of scanpaths based on filtering of fixations and similarity measures. Concerning the first part, we introduce a multiscale aggregation of fixations and saccades based on a spatial partitioning that reduces visual clutter of overlaid scanpaths without changing the overall impression of large-scale eye movements. The multiscale technique abstracts the individual scanpaths and allows an analyst to visually identify clusters or patterns inherent to the gaze data without the need for lengthy precomputations. For the second part, we introduce an approach where analysts can remove fixations from a pair of scanpaths in order to increase the similarity between them. This can be useful to discover and understand reasons for dissimilarity between scanpaths, data cleansing, and outlier detection. Our implementation uses the MultiMatch algorithm to predict similarities after the removal of individual fixations. Finally, we demonstrate the usefulness of our techniques in a use case with scanpaths that were recorded in a study with metro maps.

13:30 - 15:30
ETVIS (Eye Tracking and Visualization)
Session 1: Visualization

The Hierarchical Flow of Eye Movement
Michael Burch, Ayush Kumar, Klaus Mueller

Eye movements are composed of spatial and temporal aspects. Moreover, not only the eye movements of one subject are of interest, but a data analyst is more or less interested in the scanning strategies of a group of people in a condensed form. This data aggregation can provide useful insights into the visual attention over space and time leading to the detection of possible visual problems or design flaws in the presented stimulus. In this paper we present a way to visually explore the flow of eye movements, i.e., we try to bring a layered hierarchical structure into the spatio-temporal eye movements. To reach this goal, the stimulus is spatially divided into areas of interest (AOIs) and temporally or sequentially aggregated into time periods or subsequences. The weighted AOI transitions are used to model directed graph edges while the AOIs build the graph vertices. The flow of eye movements is naturally obtained by computing hierarchical layers for the AOIs while the downward edges indicate the hierarchical flow between the AOIs on the corresponding layers.

13:30 - 15:30
ETVIS (Eye Tracking and Visualization)
Session 2: Evaluation

Session Chair: Lewis Chuang

The Influence of Anxiety on Visual Entropy of Experienced Drivers
Gisele Gotardi, Martina Navarro, Paula Polastri, Paulo Schor, Dominic Orth, Raoul Oudejans, John van der Kamp, Geert Savelsbergh, Sérgio Rodrigues

This study tested the use of entropy to identify changes on behavior of drivers under pressure. Sixteen experienced drivers drove in a simulator wearing a head-mounted eye tracker under lowand high-anxiety conditions. Anxiety was induced by manipulating some psychological factors such as peer-pressure. Fixations transitions between AOIs (lane, speedometer and mirrors) were calculated through frst-order transition matrix, transformed to Markov probability matrix and adjusted into the entropy equation. Drivers showed greater state-anxiety scores and higher mean heart rates following manipulation. Under anxiety, drivers showed higher visual entropy, indicating a more random scanning. The randomness implies into a poorer acquisition of information and may indicate an impaired top-down control of attention provoked by anxiety.

Eye-Tracking Evaluation of 3D Thematic Maps
Stanislav Popelka

Although many 3D thematic cartography methods exist, the effectiveness of their use is not known. The described experiment comprised two parts focusing on the evaluation of two 3D thematic cartography methods (Prism Map and Illuminated Choropleth Map) compared to a simple choropleth map. The task in both parts of the experiment was to determine which of the marked areas showed a higher value of the displayed phenomenon. The correctness of answers, response time and selected eye-tracking metrics were analysed. In the first part of the experiment, a higher number of correct answers was found for Prism Maps than for simple choropleth maps, but it required more time to solve the task. The Illuminated Choropleth Map showed a higher proportion of correct answers than a simple choropleth map. During evaluation of the eye-tracking metrics, a statistically significant difference was not found in most cases.

13:30 - 15:30
ETVIS (Eye Tracking and Visualization)
Session 2: Evaluation

Visual Analysis of Eye Gazes to Assist Strategic Planning in Computer Games
Ayush Kumar, Michael Burch, Klaus Mueller

This work studies the use of a conventional eye tracking system for analysis of an online game player's thinking processes. For this purpose, the eye gaze data of several users playing a simple online turn-based checkers game were recorded and made available in real-time to gaze-informed players. The motivation behind this work is to determine if making the eye-gaze data available can help these players to predict the gaze-tracked opponent player's further moves, and also how this can be most effectively done. We also tested different orientations of the screen on which the gaze data were displayed. By our visual and algorithmic analysis we validated (1) that prediction is possible and (2) that accuracy highly depends on the moves of players throughout the game as well as on the screen orientation. We believe that our study has implications on visual problem solving in general, especially in collaborative scenarios.

16:00 - 18:00
ETRA Session 5:
Gaze based Interaction

Session Chair:
Hans Gellersen

Paper **Circular Orbits Detection for Gaze Interaction Using 2D Correlation and Profile Matching Algorithms**

Eduardo Velloso (University of Melbourne); Flavio Luiz Coutinho (University of Sao Paulo); Andrew Kurauchi (University of Sao Paulo); Carlos H Morimoto (University of São Paulo)

Recently, interaction techniques in which the user selects screen targets by matching their movement with the input device have been gaining popularity, particularly in the context of gaze interaction (e.g. Pursuits, Orbits, AmbiGaze, etc.). However, though many algorithms for enabling such interaction techniques have been proposed, we still lack an understanding of how they compare to each other. In this paper, we introduce two new algorithms for matching eye movements: Profile Matching and 2D Correlation, and present a systematic comparison of these algorithms with two other state-of-the-art algorithms: the Basic Correlation algorithm used in Pursuits and the Rotated Correlation algorithm used in PathSync. We also examine the effects of two thresholding techniques and post-hoc filtering. We evaluated the algorithms on a user dataset and found the 2D Correlation with one-level thresholding and post-hoc filtering to be the best performing algorithm.

Paper **Dwell Time Reduction Technique using Fitts' Law for Gaze-Based Target Acquisition**

Toshiya Isomoto (University of Tsukuba); Toshiyuki Ando (University of Tsukuba); Buntarou Shizuki (University of Tsukuba); Shin Takahashi (University of Tsukuba)

We present a dwell time reduction technique for gaze-based target acquisition. We adopt Fitts' Law to achieve the dwell time reduction. Our technique uses both the eye movement time for target acquisition estimated using Fitts' Law (Te) and the actual eye movement time (Ta) for target acquisition; a target is acquired when the difference between Te and Ta is small. First, we investigated the relation between the eye movement for target acquisition and Fitts' Law; the result indicated a correlation of 0.90 after error correction. Then we designed and implemented our technique. Finally, we conducted a user study to investigate the performance of our technique; an average dwell time of 86.7 ms was achieved, with a 10.0% Midas-touch rate.

16:00 - 18:00
ETRA Session 5: Gaze based Interaction

Note **Hidden Pursuits: Evaluating Gaze-selection via Pursuits when the Stimulus Trajectory is Partially Hidden**

Thomas Mattusch (LMU Munich); Mahsa Mirzamohammad (University of Jyväskylä); Mohamed Khamis (LMU Munich); Andreas Bulling (Max Planck Institute for Informatics); Florian Alt (LMU Munich)

The idea behind gaze interaction using Pursuits is to leverage the human's smooth pursuit eye movements performed when following moving targets. However, humans can also anticipate where a moving target would reappear if it temporarily hides from their view. In this work, we investigate how well users can select targets using Pursuits in cases where the target's trajectory is partially invisible (HiddenPursuits): e.g., can users select a moving target that temporarily hides behind another object? Although HiddenPursuits was not studied in the context of interaction before, understanding how well users can perform HiddenPursuits presents numerous opportunities, particularly for small interfaces where a target's trajectory can cover area outside of the screen. We found that users can still select targets quickly via Pursuits even if their trajectory is up to 50% hidden, and at the expense of longer selection times when the hidden portion is larger. We discuss how gaze-based interfaces can leverage HiddenPursuits for an improved user experience.

Paper **Contour-Guided Gaze Gestures: Using Object Contours as Visual Guidance for Triggering Interactions**

Florian Jungwirth (Johannes Kepler University); Michael Haslgrübler (Johannes Kepler University); Alois Ferscha (Inst of Pervasive Computing)

The eyes are an interesting modality for pervasive interactions, though their applicability for mobile scenarios is restricted by several issues so far. In this paper, we propose the idea of contour-guided gaze gestures, which overcome former constraints, like the need for calibration, by relying on unnatural and relative eye movements, as users trace the contours of objects in order to trigger an interaction. The interaction concept and the system design are described, along with two user studies, that demonstrate the method's applicability. It is shown that users were able to trace object contours to trigger actions from various positions on multiple different objects. It is further determined, that the proposed method is an easy to learn, hands-free interaction technique, that is robust against false positive activations. Results highlight low demand values and show that the method holds potential for further exploration, but also reveal areas for refinement.

16:00 - 18:00
ETRA Session 5: Gaze based Interaction

Paper **Improving Map Reading with Gaze-Adaptive Legends**
Fabian Göbel (ETH Zurich); Peter Kiefer (ETH Zurich); Ioannis Giannopoulos (Vienna University of Technology); Andrew Duchowski (Clemson University); Martin Raubal (ETH Zurich)

Complex information visualizations, such as thematic maps, encode information using a particular symbology that often requires the use of a legend to explain its meaning.Traditional legends are placed at the edge of a visualization, which can be difficult to maintain visually while switching attention between content and legend.
Moreover, an extensive search may be required to extract relevant information from the legend. In this paper we propose to consider the user's visual attention to improve interaction with a map legend by adapting both the legend's placement and content to the user's gaze.
In a user study, we compared two novel adaptive legend behaviors to a traditional (non-adaptive) legend. We found that, with both of our approaches, participants spent significantly less task time looking at the legend than with the baseline approach. Furthermore, participants stated that they preferred the gaze-based approach of adapting the legend content (but not its placement).

Note **Rapid Alternating Saccade Training**
Brent D. Parsons (SISSA); Richard Ivry (UC Berkeley)

While individual eye movement characteristics are remarkably stable, experiments on saccadic spatial adaptation indicate that oculomotor learning is possible. To further investigate saccadic learning, participants received veridical feedback on saccade rate while making sequential saccades as quickly as possible between two horizontal targets. Over the course of five days, with just ten minutes of training per day, participants were able to significantly increase the rate of sequential saccades. This occurred through both a reduction in dwell duration and to changes in secondary saccade characteristics. There was no concomitant change in participant's accuracy or precision. The learning was retained following the training and generalized to saccades of different directions, and to reaction time measures during a delayed saccade task. The study provides evidence for a novel form of saccadic learning with applicability in a number of domains.

16:00 - 18:00
ETVIS (Eye Tracking and Visualization)
Session 3: Applications

Session Chair:
Michael Burch

Visualizing Pilot Eye Movements for Flight Instructors
David Rudi, Peter Kiefer, Martin Raubal

The idea of using eye tracking technology in pilot training has been suggested and successfully applied in the past. At the same time, the possibilities of visualizing eye tracking data have strongly progressed. Nonetheless, little effort has been invested into exploring which type of eye tracking visualization flight instructors prefer for evaluating pilots' visual scanning strategies. This paper introduces ongoing research, which provides flight instructors with different eye tracking visualizations for assessing pilots' eye movements and evaluates those in an empirical study.

Improving the Adaptive Event Detection Algorithm of Nyström and Holmqvist for Noisy Data
Benedict Fehringer

Detecting eye tracking events such as fixations and saccades is one of the first important steps in eye tracking research. The adaptive algorithm by Nyström and Holmqvist [2010] estimates thresholds by computing a "peak velocity detection threshold" (PT) that depends on the data's noise level. However, too high thresholds might result in only few detected saccades. The present study investigated a solution with an upper bound for PT. Fixations and saccades were computed for N = 68 participants who performed a fixation task and a visual detection test. The original version of the algorithm was compared with five versions utilizing upper bounds for PT (ranging from 100 deg/sec to 300 deg/sec) according to three predefined criteria. These criteria suggest an optimal upper bound at 200 deg/sec for the utilized static and simple structured testing materials.

Silver Sponsor

16:00 - 18:00
ETVIS (Eye Tracking and Visualization)
Session 3: Applications

GaRSIVis: Improving the Predicting of Self-Interruption during Reading using Gaze Data
Jan Pilzer, Shareen Mahmud, Vanessa Putnam, Xinhong Liu, Tamara Munzner

Gaze pattern data provides a promising opportunity to create a predictive model of self-interruption during reading that could support active interventions to keep a reader's attention at times when self-interruptions are predicted to occur. We present two systems designed to help analysts create and improve such a model. We present GaRSIVis, (Gaze Reading Self-Interruption Visualizer), that integrates a visualization front-end suitable for data cleansing and a prediction back-end that can be run repeatedly as the input data is iteratively improved. It allows analysts refining the predictive model to filter out unwanted parts of the gaze data that should not be used in the prediction. It relies on data gathered by GaRSILogger, which logs gaze data and activity associated with interruptions during on-screen reading. By integrating data cleansing and our prediction results in our visualization, we enable analysts using GaRSIVis to come up with a comprehensible way of understanding self-interruption from gaze related features.

Region of Interest Generation Algorithms for Eye Tracking Data
Wolfgang Fuhl, Thomas C Kübler, Hanna Brinkmann, Raphael Rosenberg, Wolfgang Rosenstiel, Enkelejda Kasneci

Using human fixation behavior, we can interfere regions that require to be processed at high resolution and where stronger compression can be favored. Analyzing the visual scan path solely based on a predefined set of regions of interest (ROIs) limit the exploration room of the analysis. Insights can only be gained for those regions that the data analyst considered worthy of labeling. Furthermore, visual exploration is naturally time-dependent: A short initial overview phase may be followed by an in-depth analysis of regions that attracted the most attention. Therefore, the shape and size of regions of interest may change over time. Automatic ROI generation can help in automatically reshaping the ROIs to the data of a time slice.We developed three novel methods for automatic ROI generation and show their applicability to different eye tracking data sets. The methods are publicly available as part of the EyeTrace software at http://www.ti.uni-tuebingen.de/Eyetrace.1751.0.html

17:45 - 18:00
ETVIS: Panel Discussion (RoomS305)
"How can visualization make a larger contribution to ETRA?"

Enkelejda Kasneci (University of Tuebingen, DE)
Peter Kiefer (ETH, Zurich, CH)
Thies Pfeiffer (University of Bielefeld, DE)
Michael Raschke (Blickshift GmbH, DE)
Andrew Duchowski (Clemson University, US)

10:30 - 12:30
ETRA Session 6:
Social and Natural Behaviors

Session Chair:
John Paulin Hansen

Paper **Robust Eye Contact Detection in Natural Multi-Person Interactions Using Gaze and Speaking Behaviour**

Philipp Müller (Max Planck Institute for Informatics); Michael Xuelin Huang (Max Planck Institute for Informatics); Xucong Zhang (Max Planck Institute for Informatics); Andreas Bulling (Max Planck Institute for Informatics)

Eye contact is one of the most important non-verbal social cues and fundamental to human interactions. However, detecting eye contact without specialised eye tracking equipment poses significant challenges, particularly for multiple people in real-world settings. We present a novel method to robustly detect eye contact in natural three- and four-person interactions using off-the-shelf ambient cameras. Our method exploits that, during conversations, people tend to look at the person who is currently speaking. Harnessing the correlation between people's gaze and speaking behaviour therefore allows our method to automatically acquire training data during deployment and adaptively train eye contact detectors for each target user. We empirically evaluate the performance of our method on a recent dataset of natural group interactions and demonstrate that it achieves a relative improvement over the state-of-the-art method of more than 60%, and also improves over a head pose based baseline.

Paper **I See What You See: Gaze Awareness in Mobile Remote Collaboration**

Deepak Akkil (University of Tampere); Biju Thankachan (University of Tampere); Poika Isokoski (University of Tampere)

An emerging use of mobile video telephony is to enable joint activities and collaboration on physical tasks. We conducted a controlled user study to understand if seeing the gaze of a remote instructor is beneficial for mobile video collaboration and if it is valuable that the instructor is aware of the sharing of the gaze. We compared three gaze sharing configurations, (a) Gaze_Visible where the instructor is aware and can view own gaze point that is being shared, (b) Gaze_Invisible where the instructor is aware of the shared gaze, but cannot view her own gaze point and (c) Gaze_Unaware where the instructor is unaware about the gaze sharing, with a baseline of shared-mouse pointer. Our results suggests that naturally occurring gaze may not be as useful as explicitly produced eye movements. Further, instructors prefer using mouse rather than gaze for remote gesturing, while the workers also find value in transferring the gaze information.

10:30 - 12:30
ETRA Session 6: Social and Natural Behaviors

Paper **Gaze patterns during Remote Presentations while Listening and Speaking**

Pernilla Qvarfordt (FX Palo Alto Laboratory); Matthew Lee (FX Palo Alto Laboratory, Inc.)

Managing an audience's visual attention to presentation content is critical for effective communication in tele-conferences. This paper explores how audience and presenter coordinate visual and verbal information, and how consistent their gaze behavior is, to understand if their gaze behavior can be used for inferring and communicating attention in remote presentations. In a lab study, participants were asked first to view a short video presentation, and next, to rehearse and present to a remote viewer using the slides from the video presentation. We found that presenters coordinate their speech and gaze at visual regions of the slides in a timely manner (in 72% of all events analyzed), whereas audience only looked at what the presenter talked about in 53% of all events. Rehearsing aloud and presenting resulted in similar scanpaths. To further explore if it possible to infer if what a presenter is looking at is also talked about, we successfully trained models to detect an attention match between gaze and speech. These findings suggest that us-ing the presenter's gaze has the potential to reliably communicate the presenter's focus on essential parts of the visual presentation material to help the audience better follow the presenter.

Note Demo **A Visual Comparison of Gaze Behavior from Pedestrians and Cyclists**

Mathias Trefzger (Karlsruhe University of Applied Sciences); Tanja Blascheck (INRIA); Michael Raschke (Blickshift GmbH); Sarah Hausmann (Karlsruhe University of Applied Sciences); Thomas Schlegel (Karlsruhe University of Applied Sciences)

In this paper, we contribute an eye tracking study conducted with pedestrians and cyclists. We apply a visual analytics-based method to inspect pedestrians' and cyclists' gaze behavior as well as video recordings and accelerometer data. This method using multi-modal data allows us to explore patterns and extract common eye movement strategies. Our results are that participants paid most attention to the path itself; advertisements do not distract participants; participants focus more on pedestrians than on cyclists; pedestrians perform more shoulder checks than cyclists do; and we extracted common gaze sequences. Such an experiment in a real-world traffic environment allows us to understand realistic behavior of pedestrians and cyclists better.

10:30 - 12:30
ETRA Session 6: Social and Natural Behaviors

Note Paper

Scene perception while listening to music: an eye-tracking study
Jan Petružálek (University of Hradec Králové); Denis Šefara (University of Hradec Králové); Marek Franek (University of Hradec Králové); Martin Kabeláč (University of Hradec Králové)

Previous studies have observed longer fixations and fewer saccades while viewing various outdoor scenes and listening to music compared to a no-music condition. There is also evidence that musical tempo can modulate the speed of eye movements. However, recent investigations from environmental psychology demonstrated differences in eye movement behavior while viewing natural and urban outdoor scenes. Viewing natural scenes is associated with longer fixation durations than viewing outdoor urban scenes. The first goal of this study was to replicate the observed effect of music listening while viewing outdoor scenes with different musical stimuli. Next, the effect of a fast and a slow musical tempo on eye movement speed was investigated. Finally, the effect of the type of outdoor scene (natural vs. urban scenes)was explored. The results revealed shorter fixation durations in the no-music condition compared to both music conditions, but these differences were non-significant. Moreover, we did not finddifferences in eye movements between music conditions with fast and slow tempo. Although significantly shorter fixations were found for viewing urban scenes compared with natural scenes, we did not find a significant interaction between the type of scene and music conditions. It suggests that music processing does not require the same cognitive resources as the processing of visualscenes. It is supposed that the type of musical stimuli, the specific tempo, and the specific experimental procedure and the interest and engagement of participants in listening to background music while processing visual information are important factors that influence attentional processes, which are manifested in eyemovement behavior.

Enabling unsupervised eye tracker calibration by school children through games
Oleg Špakov (University of Tampere); Howell Istance (University of Tampere); Tiia Tuulia Viitanen (Tampere University of Applied Sciences); Harri Siirtola (University of Tampere); Kari-Jouko Räihä (University of Tampere)

To use eye trackers in a school classroom, children need to be able to calibrate their own tracker unsupervised and on repeated occasions. A game designed specifically around the need to maintain their gaze in fixed locations was used to collect calibration and verification data. The data quality obtained was compared with a standard calibration procedure and another game, in two studies carried out in three elementary schools. One studied the effect on data quality over repeated occasions and the other studied the effect of age on data quality. The first showed that accuracy obtained from unsupervised calibration by children was twice as good after six occasions with the game requiring the fixed gaze location compared with the standard calibration, and as good as standard calibration by group of supervised adults. In the second study, age was found to have no effect on performance in the groups of children studied.

10:30 - 12:30
EMIP (Eye Movements in Programming) Session 1

Toward Conjoint Analysis of Simultaneous Eye-Tracking and fMRI Data for Program-Comprehension Studies
Norman Peitek, Janet Siegmund, Chris Parnin, Sven Apel, André Brechmann

After decades of research, there is still no comprehensive, validated model of program comprehension. Recently, researchers have been applying psycho-physiological measures to expand our understanding of program comprehension. In this position paper, we argue that measuring program comprehension simultaneously with functional magnetic resonance imaging (fMRI) and eye tracking is promising. However, due to the different nature of both measures in terms of response delay and temporal resolution, we need to develop suitable tools. We describe the challenges of conjoint analysis of fMRI and eye-tracking data, and we also outline possible solution strategies

Data Flow Metrics in Program Comprehension Tasks
Martin Konopka, Adam Talian, Jozef Tvarozek, Pavol Navrat

Existing research in program comprehension has paid less attention to the coverage of programming concepts that were contained within the source codes used for studies. In this paper, we examine source codes covering four introductory programming concepts: branching, loops and arrays, sorting, and tail recursion. The diverse types of code fragments give rise to eye movement patterns more structured according to the control flow and data flow of the program. To facilitate analysis of this class of program comprehension strategies, we propose data flow-based metrics and describe automatic computation of the metrics. In evaluation of the proposal, we conducted a pilot study with novice and intermediate programmers. In the study with recordings from 26 programmers we compute basic fixation and saccade metrics along with a data flow-based metric.

Can We Predict Stressful Technical Interview Settings Through Eye-tracking?
Mahnaz Behroozi, Chris Parnin

Recently, eye-tracking analysis for finding the cognitive load and stress while problem-solving on the whiteboard during a technical interview is finding its way in software engineering society. However, there is no empirical study on analyzing how much the interview setting characteristics affect the eye-movement measurements. Without knowing that, the results of a research on eye-movement measurements analysis for stress detection will not be reliable. In this paper, we analyzed the eye-movements of 11 participants in two interview settings, one on the whiteboard and the other on the paper, to find out if the characteristics of the interview settings affect the analysis of participants' stress. To this end, we applied 7 Machine Learning classification algorithms on three different labeling strategies of the data to suggest researchers of the domain a useful practice of checking the reliability of the eye-measurements before reporting any results.

13:30 - 15:30
ETRA Session 7:
Clinical and Emotional

Session Chair:
Marcus Nyström

Note **Systematic shifts of fixation disparity accompanying brightness changes**

Anke Huckauf (Ulm University)

Video-based gaze tracking is prone to brightness changes due to their effects on pupil size. Monocular observations indeed confirm variable fixation locations depending on brightness. In close viewing, pupil size is coupled with accommodation and vergence, the so-called near triad. Hence, systematic changes in fixation disparity might be expected to co-occur with varying pupil size. In the current experiment, fixation disparity was assessed. Calibration was conducted either on dark or on bright background, and text had to be read on both backgrounds, on a self-illuminating screen and on paper. When calibration background matches background during reading, mean fixation disparity did not differ from zero. In the non-calibrated conditions, however, a brighter stimulus went along with a dominance of crossed fixations and vice versa. The data demonstrate that systematic changes in fixation disparity occur as effect of brightness changes advising for careful setting calibration parameters.

Note **Towards Using the Spatio-temporal Properties of Eye Movements to Classify Visual Field Defects**

Alessandro Grillini (University Medical Center Groningen); Daniel Ombelet (University of Groningen); Rijul Saurabh Soans (Indian Institute of Technology - Delhi); Frans W Cornelissen (University Medical Center Groningen)

Perimetry---assessment of visual field defects (VFD)---requires patients to be able to maintain a prolonged stable fixation, as well as to provide feedback through motor response. These aspects limit the testable population and often lead to inaccurate results. We hypothesized that different VFD would alter the eye-movements in systematic ways, thus making it possible to infer the presence of VFD by quantifying the spatio-temporal properties of eye movements. We developed a tracking test to record participant's eye-movements while we simulated different gaze-contingent VFD. We tested 50 visually healthy participants and simulated three common scotomas: peripheral loss, central loss and hemifield loss. We quantified spatio-temporal features using cross-correlogram analysis, then applied cross-validation to train a decision tree algorithm to classify the conditions. Our test is faster and more comfortable than standard perimetry and can achieve a classifying accuracy of □90% (True Positive Rate = □98%) with data acquired in less than 2 minutes.

13:30 - 15:30
ETRA Session 7: Clinical and Emotional

Paper **Scanpath comparison in medical image reading skills of dental students: Distinguishing stages of expertise development**

Nora Castner (University of Tübingen); Thomas C Kübler (University of Tübingen); Enkelejda Kasneci (University of Tubingen); Katharina Scheiter (Leibniz-Institut für Wissensmedien); Juliane Richter (Leibniz-Institut für Wissensmedien); Thérése Eder (Leibniz-Institut für Wissensmedien); Fabian Hüttig (University Hospital); Constanze Keutel (Center of Dentistry, Oral Medicine and Maxillofacial Surgery)

A popular topic in eye tracking is the difference between novices and experts and their domain-specific eye movement behaviors. However, very little is researched regarding how expertise develops, and more specifically, the developmental stages of eye movement behaviors. Our work compares the scanpaths of five semesters of dental students viewing orthopantomograms (OPTs) with classifiers to distinguish sixth semester through tenth semester students. We used the analysis algorithm SubsMatch 2.0 and the Needleman-Wunsch algorithm. Overall, both classifiers were able distinguish the stages of expertise in medical image reading above chance level. Specifically, it was able to accurately determine sixth semester students with no prior training as well as sixth semester students after training. Ultimately, using scanpath models to recognize gaze patterns characteristic of learning stages, we can provide more adaptive, gaze-based training for students.

Note **Development of diagnostic performance & visual processing in different types of radiological expertise**

Pawel Kasprowski (Silesian University of Technology); Katarzyna Harezlak (Silesian University of Technology); Sabina Kasprowska (District Hospital of Orthopedics and Trauma Surgery)

The aim of this research was to compare visual patterns while examining radiographs in groups of people with different levels and different types of expertise. Introducing the latter comparative base is the original contribution of these studies. The residents and specialists were trained in medical diagnosing of X-Rays and for these two groups it was possible to compare visual patterns between observers with different level of the same expertise type. On the other hand, the radiographers who took part in the examination - due to specific of their daily work - had experience in reading and evaluating X-Rays quality and were not trained in diagnosing. Involving this group created in our research the new opportunity to explore eye movements obtained when examining X-Ray for both medical diagnosing and quality assessment purposes, which may be treated as different types of expertise. We found that, despite the low diagnosing performance, the radiographers eye movement characteristics were more similar to the specialists than eye movement characteristics of the residents. It may be inferred that people with different type of expertise, yet after gaining a certain level of experience (or practise), may develop similar visual patterns which is the original conclusion of the research.

13:30 - 15:30
ETRA Session 7: Clinical and Emotional

Paper **Implementing innovative gaze analytic methods in clinical psychology: a study on eye movements in antisocial violent offenders**
Nina A. Gehrer (University of Tübingen); Michael Schönenberg (University of Tübingen); Andrew Duchowski (Clemson University); Krzysztof Krejtz (SWPS University of Social Sciences and Humanities)

A variety of psychological disorders like antisocial personality disorder have been linked to impairments in facial emotion recognition. Exploring eye movements during categorization of emotional faces is a promising approach with the potential to reveal possible differences in cognitive processes underlying these deficits. Based on this premise we investigated whether antisocial violent offenders exhibit different scan patterns compared to a matched healthy control group while categorizing emotional faces. Group differences were analyzed in terms of attention to the eyes, extent of exploration behavior and structure of switching patterns between Areas of Interest. While we were not able to show clear group differences, the present study is one of the first that demonstrates the feasibility and utility of incorporating recently developed eye movement metrics such as gaze transition entropy into clinical psychology.

Note **Ocular reactions in response to impressions of emotion-evoking pictures**
Minoru Nakayama (Tokyo Institute of Technology)

Oculomotor indicies in response to emotional stimuli were analysed chronologically in order to investigate the relationships between eye behaviour and emotional activity in human visual perception. Seven participants classified visual stimuli into two emotional groups using subjective ratings of images, such as “Pleasant” and “Unpleasant”. Changes in both eye movements and pupil diameters between the two groups of images were compared. Both the mean saccade lengths and the cross power spectra of eye movements for “Unpleasant” ratings were significantly higher than for other ratings of eye movements in regards to certain the duration of certain pictures shown. Also, both mean pupil diameters and their power spectrum densities were significantly higher when the durations of pictures presented were lengthened. When comparing the response latencies, pupil reactions followed the appearance of changes in the direction of eye movements. The results suggest that at specific latencies, “Unpleasant” images activate both eye movements and pupil dilations.

13:30 - 15:30
ETRA Session 7: Clinical and Emotional

Paper **Dynamics of emotional facial expressions recognition in individuals with social anxiety**

Krzysztof Krejtz (SWPS University of Social Sciences and Humanities); Katarzyna Wisiecka (SWPS University of Social Sciences and Humanities); Izabela Krejtz (SWPS University of Social Sciences and Humanities); Paweł Holas (University of Warsaw); Michał Olszanowski (SWPS University of Social Sciences and Humanities); Andrew Duchowski (Clemson University)

This paper demonstrates the utility of ambient-focal attention and pupil dilation dynamics to describe visual processing of emotional facial expressions. Pupil dilation and focal eye movements reflect deeper cognitive processing and thus shed more light on the dy- namics of emotional expression recognition. Socially anxious in- dividuals (N = 24) and non-anxious controls (N = 24) were asked to recognize emotional facial expressions that gradually morphed from a neutral expression to one of happiness, sadness, or anger in 10-sec animations. Anxious cohorts exhibited more ambient face scanning than their non-anxious counterparts. We observed a positive relationship between focal fixations and pupil dilation, indi- cating deeper processing of viewed faces, but only by non-anxious partici- pants, and only during the last phase of emotion recognition. Group differences in the dynamics of ambient-focal attention sup- port the hypothesis of vigilance to emotional expression processing by socially anxious individuals. We discuss the results by referring to current literature on cognitive psychopathology.

13:30 - 15:30
EMIP (Eye Movements in Programming) Session 2

Beyond Gaze: Preliminary Analysis of Pupil Dilation and Blink Rates in an fMRI Study of Program Comprehension
Norman Peitek, Janet Siegmund, Chris Parnin, Sven Apel, André Brechmann

Researchers have been employing psycho-physiological measures to better understand program comprehension, for example simultaneous fMRI and eye tracking to validate top-down comprehension models. In this paper, we argue that there is additional value in eye-tracking data beyond eye gaze: Pupil dilation and blink rates may offer insights into programmers' cognitive load. However, the fMRI environment may influence pupil dilation and blink rates, which would diminish their informative value. We conducted a preliminary analysis of pupil dilation and blink rates of an fMRI experiment with 22 student participants. We conclude from our preliminary analysis that the correction for our fMRI environment is challenging, but possible, such that we can use pupil dilation and blink rates to more reliably observe program comprehension.

Eye Movements in Code Review
Andrew Begel, Hana Vrzakova

In order to ensure sufficient quality, software engineers conduct code reviews to read over one another's code looking for errors that should be fixed before committing to their source code repositories. Many kinds of errors are spotted, from simple spelling mistakes and syntax errors, to architectural flaws that may span several files. However, we know little about how software developers read code when looking for defects. What kinds of code trigger engineers to check more deeply into suspected defects? How long do they take to verify whether a defect is really there? We conducted a study of 35 software engineers performing 40 code reviews while capturing their gaze with an eye tracker. We classified each code defect the developers found and captured the patterns of eye gazes used to deliberate about each one. We report how long it took to confirm defect suspicions for each type of defect and the fraction of time spent skimming the code vs. carefully reading it. This work provides a starting point for automating code reviews that could help engineers spend more time focusing on the difficult task of defect confirmation rather than the tedious task of defect discovery.

13:30 - 15:30
EMIP (Eye Movements in Programming) Session 2

Gaze Behaviour in Computer Programmers with Dyslexia - Considerations Regarding Code Style, Layout and Crowding
Ian McChesney, Raymond Bond

Previous work investigating the eye movements of computer programmers with dyslexia suggests that the gaze behaviour expected of dyslexic readers when processing natural text does not consistently manifest when programmers with dyslexia read program code. Instead, the observed eye movements of programmers with dyslexia appear to represent a complex hybrid of gaze behaviour both typical and atypical of dyslexic readers. Building on this work, this paper explores the possible impact of code style, layout and crowding on the reading behaviour of programmers with dyslexia. Related work on the phenomenon of crowding in the dyslexia literature is used to inform a possible experimental design to explore the effect of crowding in this context.

Notes

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Special Thanks to SWPS University for the Venue

SWPS University of Social Sciences and Humanities was established in 1996. It is the first private university in Poland. The University has been ranked by the Ministry of Science and Higher Education as the leading higher education institution offering Social Sciences programs in Poland.

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